ON PERIODICAL CHANGE

OF

TERRESTRIAL MAGNETISM,

BY

F. W. SCHULZE.

READ BEFORE THE NORTH-CHINA BRANCH OF THE ROYAL ASIATIC SOCIETY, ON THE 14TH JUNE, 1878.

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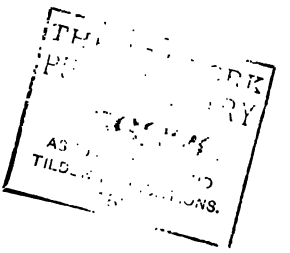

DEDICATION.

To His Excellency

ADMIRAL BARON WÜLLERSTORFF,

(Imperial Austrian Navy,)

Formerly Commodore of the "*Novara*"

Circumnavigation Expedition, Minister of Marine, &c.,

this Essay is respectfully dedicated, as a tribute to His Excellency's scientific and professional Prominence; especially in acknowledgment of His Excellency's diligent, elaborate and profound Meteorological Investigations.

FRITZ W. SCHULZE.

Shanghai, 20th January, 1879.

PREFACE.

Not without diffidence I present these pages to the public, on account of their being written in a language, which is not my native one; I may not always have succeeded to express my ideas in words, best suited to convey my exact meaning correctly; the more so, as a plain sailor can hardly be expected to be very proficient in nice penmanship; my excuse for writing on magnetism at all is, that a navigator not only has a right, but a duty, to occupy himself with anything connected with safe navigation, on which magnetism certainly has a direct influence; because without the magnetic needle and a knowledge of its various properties, modern navigation would never have attained the Eminence in the world's commerce, progress and civilisation, which it actually has achieved.

On account of my frequent absence from Shanghai during the reading of the proof sheets, I have to apologize for some misprints, that have remanied undetected, although the Editorial Committee of the Society, especially the late Honorary Secretary, Joseph Haas, Esq., have done much to eliminate many mistakes of that class; most of them owe their origin to not sufficiently legible corrections of the manuscript.

Some of my assertions may, like every new idea, appear startling at first, and be received with distrust, experiencing the unenviable fate of being treated superciliously; I shall possibly have no time, to pay much attention to criticisms of

such a character; but I will be sincerely thankful to those, who might expose any errors, which I may have committed, because my intention has certainly not been to propagate wrong conceptions, but to elucidate, if possible, TRUTH.

I am happy to be informed, that this paper has had already one favourable result; the accomplished and indefatigable director of the magnetic and meteorological observatory at Zi-ca-wei has investigated the present state of the magnetic elements in the same localities in the vicinity of Shanghai and Woosung, as Sir Charles Shadwell and Sir Everard Home many years ago. But such observations would be much more useful, if arrangements could be made to take them *simultaneously*; perhaps many officers connected with the Imperial Chinese Naval Department would be delighted, to grant their valuable assistance.

Though some ideas, which I have advanced, may have been dealt with by others previously, I trust, that sufficiently interesting matter will be found in this present Essay, which can claim to be novel and original, and I hope not unworthy of consideration.

I am convinced, that I have approximately at least given the main features of a true theory of the Periodical Changes of Terrestrial Magnetism; at the same time I am prepared frankly to confess, that for want of better information my judgment may have been led astray on some points; "*errare est humanum*"—and in nature, in time and in eternity the wise, beautiful and irrevocable laws of THE GREAT ARCHITECT OF THE UNIVERSE alone are infallible; man is not.

F. W. S.

Steamer *Swatow*, March, 1879.

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PERIODICAL CHANGE OF TERRESTRIAL MAGNETISM.

By F. W. Schulze.

Chapter I.

GLANCING over the contents of Whitaker's Almanack for 1878, my attention was called to the remarks in a short article on Terrestrial Magnetism, "that the dip, like the decli-"nation, is subject to secular, and other variations, the true "laws of which are not yet understood, etc."

Thinking it possible to give a satisfactory account of these changes, I herewith attempt a modest essay to do so.

According to Miller and Pouillet's, "Lehrbuch der kosmischen Physik," Braunschweig, 1856, the variation in Paris has been Easterly before 1663 decreasing. By Sir James Ross, the latitude of the magnetic North Pole is in the parallel of 70° N.; and bearing in mind, that the magnetic needle (if not deflected by local attraction), points to the magnetic pole, it is only natural to suppose, that prior to 1663, the magnetic North Pole must have been somewhere to the northward and eastward of Paris, moving towards the meridian of Paris probably in the latitude of 70° N. and passed near the meridian of Paris in 1663, in which year the variation was Zero; then the magnetic pole continued its westerly movement until 1814; the variation attained in that year its western maximum of 22° 34'. Since then, the pole continuing its westward motion, the westerly variation at Paris decreasing, until about the year 1965, the pole passes near the meridian of 180°, by the west of Paris, when at the latter place the variation will become Zero, and becoming easterly again afterwards attaining its eastern maximum when the pole passes the meridian of 90°, east of Paris, in about the year 2116; then the eastern variation at Paris will decrease becoming Zero, when the magnetic pole returns to the meridian of Paris, about the year 2267.

For illustration, take a terrestrial globe, and a ball of twine and attach *the end* of the twine to the geographical position of Paris; then place the ball on the same meridian, but on the parallel of 70° N. lat.; in which latitude perform an act of pa-

rallel sailing by means of the ball, to the westward, slacking the twine as required, but keep it sufficiently tight to represent a segment of a great circle; after passing the meridian of 180°, roll in the twine as required, until the ball returns to the meridian of Paris, in 70° N. lat. whence it departed. The direction of the thread has undergone the same variations, that the magnetic meridian of Paris is subject to, on the surface of our earth.

It is true the variation at Paris, would change exactly the same way, if in 1663, the magnetic pole had been in 70° N. lat. and 180° long. (from Paris), shifting in an easterly direction towards the meridian of Paris; but, recollecting that the dip of the needle increases, when we approach a pole, it must be the same thing if the pole approaches us; now the inclination at Paris is decreasing since 1671, the earliest reliable record (given in the above quoted work on cosmic physics) at my command. Therefore the variation pointing to the northward, and westward of Paris as the present position of the magnetic pole, and the dip of the needle indicating it is moving away from Paris, it cannot be in an easterly direction, but must be westerly, at least as long as no valid reason exists, to suppose that the magnetic pole changes its latitude also.

The inclination has probably been decreasing since 1168, when it must have been a maximum (the magnetic pole passing then between the true one, and Paris); it will become a maximum about the year 1965, and then increase again until about the year 2267, when the magnetic pole will return to the meridian of Paris.

The secular variation of the compass shews, that the magnetic pole is moving round the true pole, and the inclination decides, that it must be from east, towards the west; at about the rate of 151 years for the quadrant (from the meridian of Paris in 1663, to 90° west of Paris in 1814), or about 604 years for a complete revolution, or at the yearly rate of about half a degree at a rough estimate.

An inspection of Duperrey's chart of magnetic meridians, shews the irregularity of those curves; therefore the calculations introduced cannot claim to be mathematically exact, the full truth perhaps will only be learned by careful observations, and experience of future centuries.

Now, take again a globe, and construct roughly a movable system of magnetic meridians around it, with a circle equidistant from the magnetic poles, to indicate the magnetic equator; then place the magnetic North Pole on the parallel of 70° N. lat. and move the magnetic pole on that parallel round the true

one, from east towards the west; you will then have a fair representation of the movements of the whole system of magnetic lines, as it really occurs on our earth; a precession of the magnetic equator on the geographical one from east, towards the west, will take place, and a nutation of the magnetic poles round the true ones, in the same direction.

In this chapter we have seen how the secular changes are taking place, in the following one I hope to shew more explicitly the reasons why.

Chapter II.

Since writing the first chapter I have been favoured by the kindness of a friend (to whose valuable assistance I am much obliged in compiling these lines) with a copy of "Magnetism and Deviation," by John Merrifield, LL.D., F.R.A.S., etc., London, 1874, in phich I find on page 15, the following passage:—

"Professor Barlow, in his Essay on Magnetic Attraction, says, "all these variations can be accounted for by supposing the "Magnetic Poles to revolve round the terrestrial ones from "West to East, at about 20° from the latter in periods of about "600 years. Sir W. Hamilton gives a contrary direction to the "revolution, and states the period to be 900 or 1,000 years."

I am not astonished that others should have conceived similar ideas to mine, before me. However, Professor Barlow gives a wrong direction of the revolution, and Sir W. Hamilton, allows perhaps too many years for its completion.

Commander W. Walker, R.N., in his book, "The Magnetism of Ships and the Mariner's Compass," London, 1863, page 8, speaking of Columbus, who had discovered the variation of the Compass, writes as follows:—"On his return to Spain his statement, "that the direction of the Compass had varied was not believed.

"Although other Navigators had observed and announced "the variations of their Compasses, the learned of those times "would not admit the fact, they rather choose to charge sea-"men with ignorance, and inaccuracy in their observations, "then admit errors in the principles established by themselves.

"Pedro de Medina, in his Arte de Navigar, 1545, denies the "variation of the Compass; Martin Cortez, in a treatise on "Navigation printed at Sevilla before 1556, treats it as a thing "completely established. So here we see, that a period of 60 "years elapsed from the time of Columbus, observing and re-"porting the variation of the Compass before the truth of its "existence was admitted."

I hope it will require less time, before the truth of what I may be permitted to call "The Rotation Theory" will be admitted.

Mr. Merrifield gives the date of Captain Ross's discovery of the Magnetic North Pole, the year 1830. According to the theory deduced in the preceding chapter the Magnetic Pole must have been in 90° W. of Paris, in 1814. Moving from that year to 1830, at about 35′ 45″ per year nearly, to the Westward, =9° 32′, which would place the Magnetic Pole in 99° 32′ West of Paris, or about 97° 12′ West of Greenwich; Sir James Ross found it 96° 42′ West of Greenwich, half a degree from where I would place it approximately; I consider this the most conclusive proof of the soundness of the basis upon which my theory is founded.

From the same book of Mr. Merrifield's, I see that Capt. E. J. Johnson, R.N., F.R.S., places the maximum (24° 27′) of Western variation in 1815, but Colonel Beaufoy gives 24° 21′, as maximum in 1819, less modern observations, owing to the then still more imperfect instruments, can therefore hardly have been very correct, and calculations based upon them cannot be very reliable; however, they are quite sufficient to establish the principle in question firmly.

And now we will try to investigate the cause of this Magnetic Polar rotation.

Allowing that the thermometer rises one degree (celsius) for every 90—100 feet, towards the centre of the earth, (after Müller and Pouillet, Lehrbuch der kosmischen Physik), "at "a depth of about 10,000 feet water would boil, and at about "20 nautical miles, basalt and iron would melt," but I will be liberal and allow 25 miles below the surface of the earth as the limit, where we would meet a fiery molten mass.

According to "The Border lands of Geology and History" by Thomas W. Kingsmill, Shanghai and London, 1877, by Mr. Mallet's "Physico-chemical Theory," "the earth is now a ball "entirely, or in the main solid, but of high temperature." In the same work Mr. Kingsmill tells us of Sir W. Thomson, "but "although he rejects a fluid nucleus (of the earth) he acknow-"ledges, that the absence from the sea of long period tides is "not easily explained without admitting a considerable degree "of yielding." "If the interior of the earth were liquid and its "crust composed of so rigid a material as steel, and 800 miles "thick, it would yield to the deforming influences of centrifugal "force, and the attraction of the sun and moon, as if it were "India rubber; under such circumstances, as the whole mass "of the earth would be free to move, there could be no flow of

"tides, sea and land yielding equally to external influences."

I will not enter the field against Astronomers and Geologists; I am content to let them fight their own battles; probably the truth lays in the middle: "les extrêmes se touchent;" therefore I will try to steer a pretty clear mid channel course between the Scylla of solid ball, and the Charybdis of fluid nucleus theories.

Presuming at about 25 miles below our earth's surface the heat intense enough to melt all known rocks and metals, I should think it very unlikely, that the limit between solid crust and fluid interior were defined, as if cut off with a knife; I think one would be gradually verging into the other, more or less in the following order:—Outside solid crust about 25 miles; then accumulating solidifying, semi-liquid slake, succeeded by molten fiery mass. Now, let us consider what would be the pressure of such a mass at about 2,000 miles from the surface on a square foot.

Accepting the specific gravity of the earth as five times more than distilled water (according to F. Reich, 5·58, and Baily 5·66), then a column of 2,000 nautical miles = 12,160,000 feet deep × 1 feet × 1 feet of distilled water at 60·5 lbs. per cubic foot, will weigh 785,680,000 lbs. = 328,428 tons, multiplied by 5 (specified weight of earth roughly) = 1,642,140 tons pressure upon a square foot on the surface of the earth, the same column if placed upon a square foot at 2,000 miles below the surface would probably weigh less—(I am not prepared to say how much)—therefore we will disallow a whole million of tons, and still the enormous weight of 642,140 tons remains; but even then there is such a tremendous pressure upon the square foot, that I believe no molten mass of whatever high temperature could remain liquid under such a stupendous force, but would obtain a state of almost inconceivable density, that steel compared to it would be like cheese.

Late experiments have shewn, that almost all known gases by application of extreme cold, and high pressure can be forced into the liquid aggregate state first, then into the solid state afterwards; and since it is assumed that our whole earth from a gaseous state of high temperature cooled down into its present condition, I cannot be far wrong in representing the nucleus of the earth as possessing indeed an enormous high temperature, but solidified by excessive superincumbent pressure.

These suppositions being accepted as approximately correct, would give us a body of "a considerable degree of yielding," to account for the absence from the sea of long period tides,

and still not so elastic as India rubber, as not to shew any tides of the sea at all.

Allowing under the solid but sufficiently yielding crust of the earth a fiery liquid, with a fiery solid nucleus within, we must allow that the influence of the same heavenly bodies, which cause the tides of the liquids outside the earth (the Ocean) will do the same with the fiery Ocean within; and this daily interior flood wave will cause a retardation of revolution in the interior fluid mass in exactly the same manner, as it does in the Outer Ocean; it causes a westward tendency in the former as well as in the latter, and which I must suppose to be too well and generally understood, that I need not enter here into the explanation; because it is not my object to explain things which others have done much better than I can; but to demonstrate if possible the nature, and causes of the magnetic needle's periodical variations.

Admitting this daily retardation of the fluid interior inclusive the solid nucleus within it (like a sluggish compass card, that remains behind, when the ship's head moves round), it does not matter whether we say, in about 604 years, the outside shell of the earth makes one revolution ahead of its contents, or whether we say, the latter remains one revolution behind the former; the effect is the same, provided we can prove the nucleus of the earth to be the carrier of Terrestrial Magnetism; because in that case the nucleus with its Terrestrial Magnetism would be like a powerful magnetic needle (suspended in a spherical compass bowl), moving in a liquid (like in an ordinary liquid compass).

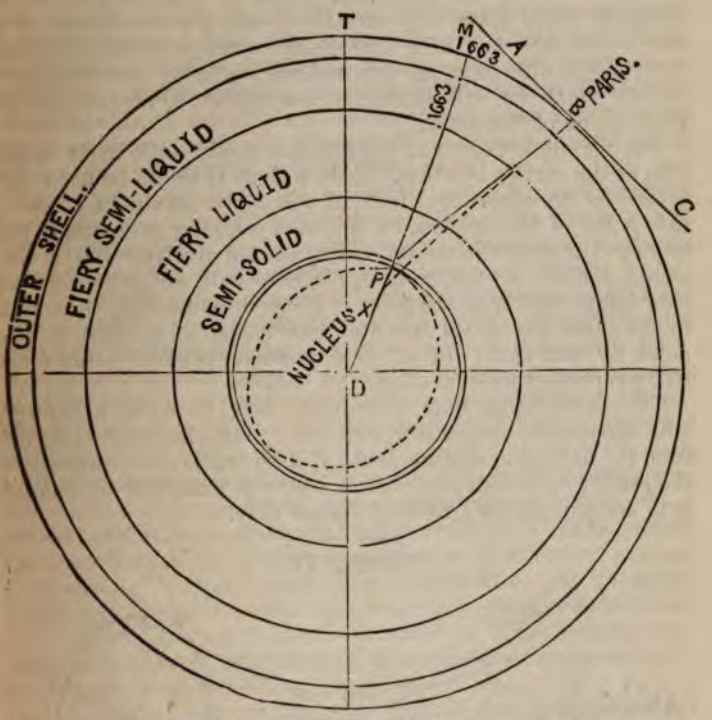
In the next chapter it will be attempted to shew the high probability why the nucleus of the earth should be the carrier of Terrestrial Magnetism.

Chapter III.

In the accompanying figure, let M represent the magnetic pole in 1668, passing between the true North Pole T and the geographical position of Paris. A—C is the horizontal line at Paris, and the angle A B P of 75° the assumed maximum dip of Paris in the same year, probably near the truth; P is a point in the interior of the earth, where the inclination needles from, the surface pole M and Paris, would intersect at the pole of the nucleus P, fixing as it were, the latter by crossbearings,

I am aware, that in reality this is not exactly the case, but do not doubt that a good mathematician could easily lay down

the unknown point X accurately, the position of the actual magnetic pole upon the earth's nucleus :—



Commander W. Walker, R.N., in the before mentioned book, says, (page 17), after giving a list of bodies capable of magnetism besides iron, "Sir W. Harris found, that by condensing "metals, their magnetic energy was increased, and that sub- "stances remain magnetic or take up magnetism more quickly, than they part with it."

This seems to imply, that magnetism can be generated in bodies by increasing their density, or, as I may say: if the density of bodies is increased by external force, then the latter performs partly the work, which previously affinity had to do, in keeping the molecules of the bodies together, and hitherto latent affinity becomes free, putting in an appearance as magnetism; or, by high pressure, a certain amount of affinity of bodies, through inereasing their density

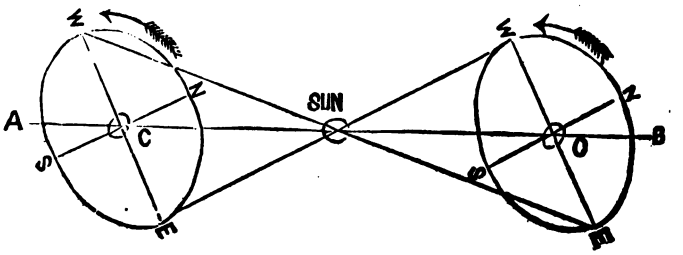
mechanically, becomes free and translated into magnetism. For fuller exposition of this view see first appendix.

Now I believe the enormous power of gravity a couple of thousand miles below the surface of our planet, of which a rough estimate has been introduced in the preceding chapter, sufficient to disengage enough molecular affinity and translate it into what we call terrestrial magnetism, to account for all phenomena of the latter.

The magnetic matter of the nucleus would settle itself in the axis of the earth's rotation, because there it would be least disturbed by the centrifugal force of the daily revolution; round the poles of the nucleus, all bodies of a higher magnetic capacity contained in the molten mass between nucleus and crust, would collect, especially iron, nickel, cobalt, etc., the same as iron filings gather to the poles of a magnetic needle; or much in the same way as we arm a natural loadstone magnet at the poles by soft iron; the whole magnetic apparatus would most likely represent an oval shape.

The explanation here introduced may be right, or wrong, still terrestrial magnetism tells us by the inclination needle from its residence, and no doubt also its cradle, the nucleus of the earth; "J'y suis, j'y reste," and my principal endeavour is to account for its *periodical changes* only.

Chapter IV.



No. 1 No. 2

Figure No. 1 is the spheroidical form of the earth at the summer solstice; A B is the plane of the ecliptic; W E the plane of the equator; N S the polar axis, and to the right is the sun.

During the summer solstice the sun attracts E more than C or W; the effect of this would be to place N S at a right angle with A B in the direction of the arrow; this is prevented by the centrifugal force of the earth's daily revolution from west to east, which brings constantly other masses of the revolving

earth under the stronger point of attraction of the sun in E; the consequence is a circulation of the earth's more yielding fluid interior, as a result of the parallelogram of forces brought to bear upon it; this circulation, if graphically illustrated, would represent an oval shape, the greater axis of which would be congruent with the axis of our planets magnetic nucleus.

In figure No. 2 is the earth at the winter solstice; W is more attracted than C and E; the tendency is to elevate N S at right angles to A B in the direction of the arrow; the influence upon the interior is the same as in fig. No. 1.

Place sun and moon for ever on the equator, or place them for ever at the poles, and the magnetic axis of the earth would soon coincide with the axis of rotation, because the interior circulation would then be deprived of its reason to exist.

It will be seen that during the summer solstice the influence of the sun's attraction must be greater in the northern hemisphere, which will cause the greater amplitude of magnetic fluctuations during the summer months; during the winter months the sun's attractive power must be less in the northern hemisphere, consequently also the amplitude of hibernal magnetic fluctuation.

During the equinoxes the sun's attraction is impartially exercised in both hemispheres, and now the moon's influence becomes to be most apparent, her attractive power being so much greater than the sun's, because she is so much nearer the object of attraction; add to this the celerity with which she constantly changes her position and it will be accounted for why Father Secchi says: "the annual disturbances of the magnetic ele-"ments are at a maximum at the equinoxes, and at a mini-"mum at the solstices."—(Merrifield.)

The magnetic equator laid down on a terrestrial globe almost coincides with the plane of the ecliptic in the Atlantic Ocean; from the interior of South America it runs in a W.N.W. direction towards the geographical equator and follows close to the latter a parallel course to the same across the Pacific; it crosses the geographical equator where the *plane of ecliptic cuts* the latter, and then again follows an almost parallel course to the geographical equator through the Indian Ocean; in the interior of Africa again it almost coincides with the plane of the ecliptic, substantiating as I think, my supposition, that the eccentricity of the earth's magnetic axis may be due to the tendency of the axis of rotation to set at a right angle to the plane of the ecliptic counteracted by the daily revolution round the axis of rotation.

Chapter V.

Month.	1st	2nd	Month.	1st	2nd
	′	°		′	°
Jan.	6· 7	— 1·90	July	12· 1	+15·04
Feb.	7· 4	— 0·15	August	13· 0	+14·43
March	11· 9	+ 2·74	Sep.	11· 8	+11·75
April	13· 9	+ 6·88	October	10· 3	+ 7·97
May	13· 5	+10·92	Nov.	6· 9	+ 3·25
June	12· 5	+13·94	Dec.	5· 0	+ 1·32

In the first column of above table is the mean amplitude (or angle comprised between the greatest eastern and western deviation of the needle from the mean daily variation) per month, as observed at Göttingen in minutes and tenths of arc; in the 2nd column is the result of six years' observations at Berlin, from 1829 to 1834, expressed in degrees and hundredths Réaumur, giving the mean temperature of every month.

It will be seen that the maxima of the needle's mean monthly variation in the first column does not coincide with the maxima of the mean temperature in the 2nd column, which seems clearly to prove, that thermo-electricity has not much to do in causing the daily variations; in June and July the mean monthly variations are not so great (as in the two preceding months), although they have a higher mean temperature; the reason is because on the first of July the sun is in Aphelion, and his attraction decreases inversely, as the square of his distance increases.

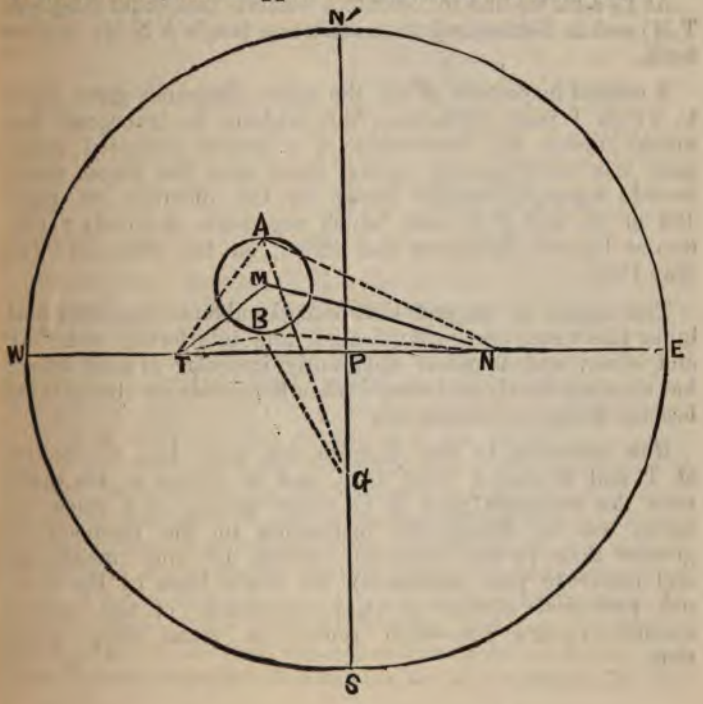
The table also shews that not in January and February, when the mean temperature is least in Central Europe, diurned variation attains a minimum, but in December, when the sun is farthest away from the northern hemisphere on account of his maximum southerly declination; another proof, that periodical change of variation cannot be dependent upon thermo-electricity produced by the sun, as supposed by many; but the greater or lesser proximity of the celestial bodies and their ever varying position principally must be looked to, to account for these periodical changes.

Unfortunately from the southern hemisphere I have no material at hand, beyond the scanty information, that the direction of the needle there is subjected to the same changes, as in

the northern hemisphere, but in an opposite direction; I have however no doubt that there the maximum of daily variation must take place about Christmas, the sun being then in Perihelion and attaining his greatest southern declination.

At the instigation of Humboldt, in the years 1828 to 1830, hourly magnetic observations were taken on previously arranged days at Berlin, Freiberg, Nicolayew and Kasan, by which a remarkable parellelism of the needles changes was proved; still more so by the labours of the Magnetic Society under the presidency of Professor Gauss, about the year 1838, to which twenty-seven observations belonged, from St. Petersburg to Dublin, from Upsala to Milan.

The following well established facts are the result of their labours; the diurnal variations are not local, but alike in places of nearly the same geographical longitude (no doubt still more so in the same magnetical longitude); if in one place a minimum of variation occurs, 90° east and west of the same, maxima will occur, but in opposite directions to one another:—



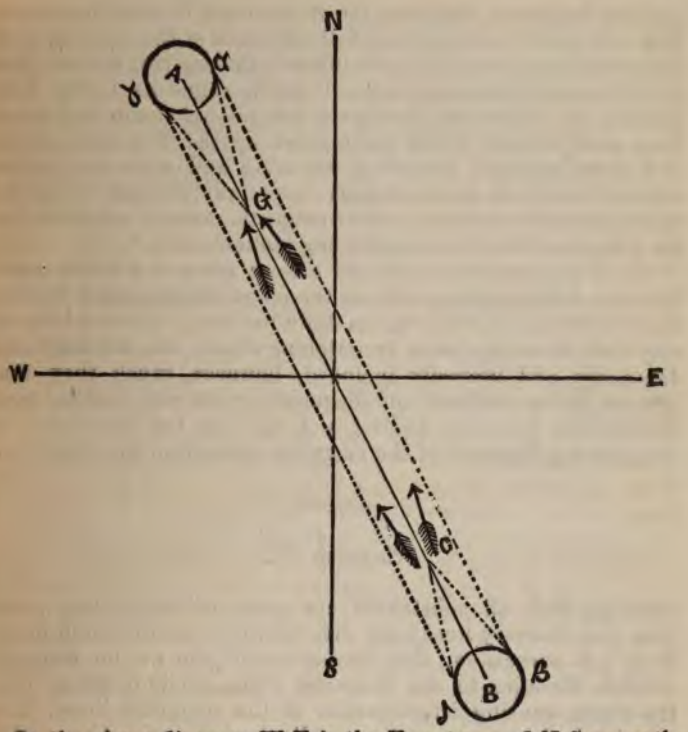
The above figure is the northern hemisphere in polar projection; N' E S W is the equator, P is the geographical pole, M the magnetic one; T is intended for the geographical position of Toronto, N the same for Nertschinsk, G the same for Göttingen, W E is an east and west line; N' S a north and south one. Toronto and Nertschinsk are about 180° of long. from one another, Göttingen is nearly in the middle between the two. From a diagram on page 495 of Müller and Pouillet's work, it can be seen that a maximum of easterly variation occurred at Toronto on the 27th and 28th August 1841. Angle B T M of present diagram at 1 a.m., when at Nertschinsk a western maximum (angle M N B) occurred, indicated by the dotted lines T B and B N, converging at the point B to the southward of the mean magnetic pole M; another maximum of eastern variation occurred at Toronto at 1 p.m., and at Nertschinsk was a maximum of western variation at 2 p.m.

At 11 a.m. we find in Toronto a western maximum (angle A T M) and in Nertschinsk an eastern one (angle A N M), and so forth.

A careful inspection of all the other diagrams given (and to which I must refer here, not wishing to transgress too much), makes the impression of a clearly indicated magnetic tide wave passing several times over the places mentioned; especially clearly shewn by the diagram on page 492 of M. and P.'s work, which represents the daily variation at Upsala, Göttingen and Milan, on the 28th and 29th May 1841.

This seems to suggest that indeed subterranean solar and lunar tide waves occur complicated, and interfering with one and other, and therefore apparently irregular at neap tides; but showing clearly and simple when both solar and lunar tides become united to a single one.

Now referring to our diagram (on page 11), the needle at T and N cannot point to A and B, unless at the same time the magnetic pole is in those places, and since we know, that in Europe the inclination in the forenoon is greater than in the afternoon (about 10 a.m. maximum and about 10 p.m. minimum), we would have by the diurnal periodical change a clear indication of the actual magnetic pole's revolution round its mean daily position.



In the above diagram W E is the Equator, and N S a north and south line; G is the assumed position of Göttingen in the northern hemisphere, C is the same of the Cape of Good Hope in the southern hemisphere; A is the magnetic North Pole, B the magnetic South Pole, and A B consequently the axis of Terrestrial Magnetism. Now, when in G the eastern maximum A G α of daily variation occurs, at C the western maximum β C B occurs, and the magnetic axis A B is transferred to $\alpha\,\beta$; the reverse takes place, when in the northern hemisphere the maximum of daily western variation A G γ occurs, in the southern hemisphere an easterly maximum δ C B must occur, and the magnetic axis is shifted from A B to $\gamma\,\delta$. Since it is understood that the poles of the needle point towards the magnetic poles of the earth, and since the inclination needle shews that the seat of Terrestrial Magnetism (see 3rd chapter) is deeply below the surface of our planet, the only

natural inference that can be drawn must be that the attraction of sun and moon influence the nucleus of the earth in such a manner as to draw it bodily towards themselves, and so force it to circumscribe a circle with its centre round its mean daily position by following closely the movements of sun and moon from east to west; boldly pointed out by the variation needle at full and change; flickering, wavering and uncertain, when sun and moon are in quadrature; especially if we allow around the poles of the nucleus a softer magnetic matter, collected like an armisture from the surrounding molten mass.

But the centre of the nucleus cannot describe a circle round its mean daily position, without the magnetic poles also describing a circle around their mean daily position; a fact which always will be recognisable by watching closely the diurnal variations, dip and intensity included, however, much they may appear to be confused and disguised by the ever shifting positions of the heavenly bodies, and also by the increasing or diminishing distances of the magnetic poles from the observer.

Chapter VI.

Knowing that all substances are more or less magnetic, and that they are very unequally divided in the earth's solid crust, it is not surprising, that deviations of the needle from its straight direction to the Magnetic Poles should occur all over the world, causing irregularities of the magnetic lines; they are simply deviations of the needle caused by local attraction of Continents, Islands, the presence of rich deposits of magnetic substances in the vicinity, &c.; Müller and Pouillet give two points of greatest magnetic intensity on the surface of the Northern hemisphere: one in North America, and the other in Northern Asia.

For illustration, I extract one very striking instance from Dr. C. Rümcker's Handbuch der Schiffahrtskunde, Hamburg, 1857, translating from page 888, as follows:—"One of the "most remarkable phenomena of this kind is on the Northern "Coast of the Gulf of Finland, within the headland of "'Hangoe,' near the Jussary Cliffs; vessels of 12 to 15 feet "draught may pass to the Eastward of Jussary Gadder, when, "in line with Western Gadd and Lerharn, all compass needles "in 10 fathoms will turn 180° round their axis, returning after-"wards to the usual direction."

Captain Duperrey's charts of magnetic lines shew a remarkable parellelism of Magnetic Meridians between the true and Magnetic Poles, especially in the Northern hemisphere which can be best accounted for, if we admit the circulation of magnetic matter round the nucleus, deflected from the axis of rotation by the nutatory influences of the principal Celestial bodies, see 3rd chapter,

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Chapter VII.

RECAPITULATION AND CONCLUSION.

Reviewing briefly the ground we have travelled over in the preceding chapters, it will be recollected, that in the first one an explanation is given, how secular change of variation is effected; the Magnetic North Pole moving round the true one in about latitude 70° N., and about 604 years from East to West; the great closed curve of no variation divides the globe nearly in a hemisphere of Westerly variation on the right hand (looking from the Magnetic North Pole towards the true one), and the hemisphere of Eastern variation to the left (the latter enclosing an oval of Western variation in Eastern Asia); move a system of magnetic lines around the Terrestrial Globe from East to West, keeping the Magnetic North Pole on the parellel of 70° N. latitude, and the phenomena of secular variation are almost mathematically exact represented.

In the 2nd chapter it is tried to reconcile the conflicting theories of fluid interior and solid ball, in regard to the earth's internal structure, as advanced each by high authorities; introducing gravity as a highly probable agent to compress the nucleus of our planet, although of the highest temperature into a solid body of the utmost density; and subterranean tide waves are pointed out, as most likely to cause one retardation of revolution of the nucleus, suspended within a molten mass, in about 604 years.

The 3rd chapter shews by means of the inclination needle, that indeed the nucleus of our planet must be the seat of Terrestrial Magnetism, and the whole similarity of our globe to the ordinary liquid compass; the solid nucleus being the magnetic apparatus suspended near the centre of the earth by fiery liquid mass; also the possibility is hinted at, that the excessive force of gravitation towards the Terrestrial centre might be the cause of Terrestrial Magnetism. The likelihood is

represented of the whole magnetic central apparatus having an oval shape, and that the divergence of the magnetic axis from the axis of rotation may be a compromise between the centrifugal force of the earth's quotidian revolution, and the tendency of the celestial bodies to elevate the rotatory axis of the fluid interior at right angles to the ecliptic (owing to the spheroidical shape of the earth), by an ecliptic circulation of fluid mass.

In the 4th chapter sun and moon are called upon, to explain by their attraction and different positions at various times of the year the periodical annual changes, and the improbability is shewn of thermal-electricity being the cause of them, as most authorities on this subject seem to have surmised.

In the 5th chapter, it is shewn how a daily displacement of the magnetic axis takes place; and since that can hardly be done, unless the magnetic body itself be displaced, it must be accepted as proved, that the magnetic terrestrial nucleus itself is being removed, attracted towards sun and moon, and thereby describing a circle round its mean daily position from East to West, following the movements of sun and moon, causing thereby a daily nutation of the actual Magnetic Poles round their mean daily position; this actual displacement of the nucleus in the direction of sun and moon, when both pass the meridian together would to my mind account better for a *flood wave* occurring 180° away from the meridian passage, than the best calculation I have ever seen, but never clearly comprehended, concerning this phenomenon.

What Humboldt has called magnetic storms is perhaps most likely to happen, when perigee and full moon occur together, especially at the time of perihelion; and the inhabitants of volcanic regions may then stand by for subterranean squalls. The diurnal nutation of the magnetic poles may be obscurely indicated only, sometimes by the declination needle for reasons pointed out; but it is imperatively proclaimed by dip and intensity, which clearly establish an approach of the magnetic pole during twelve hours towards the observer and the departure from the same during another twelve hours.

The result of these various movements is an epicycloidal track of the magnetic poles round the true ones in about 604 years from east to west.

The 6th chapter treats on some minor matters, pointing out the probable influences of local attractions, etc.

Many ideas which suggested themselves while writing, I have excluded, as not immediately bearing upon this subject; but perhaps may add them on some future occasion, as an appendix.

My sources of information have been mentioned in the body of these pages.

I trust it can be admitted in fairness to the writer, that nowhere wild speculations, which cannot be substantiated, have been advanced; but that everywhere only natural inferences have been drawn from established facts.

I cannot close this essay without acknowledging gratefully my indebtedness to Captain J. H. P. Parker, Commander of the China Navigation Company's steamer *Newchwang* for the many facilities and valuable assistance rendered me, while writing the preceding chapters.

Owing to the limited material at my command, when compiling these pages, my judgment may have erred on minor matters; but I believe to have given *at least in rough contours* a correct theory of Periodical Change of Terrestrial Magnetism.

Note.—Since the manuscript has been returned to me to see the proofs of the woodcuts, I have had an opportunity to read Mary Somerville's "Connection of the Physical Sciences," in which the view is advocated, that Terrestrial Magnetism owes its existence to induction by electricity, evolved by the earth's revolution around its axis; but I am more in favour of Sir W. R. Grove's opinion, who in his "Correlation of Physical "Forces," London 1874, page 9 says:—"But magnetism may "now be said with equal truth to be the cause of electricity, "and electrical currents may be referred to hypothetical mag- "netic lines; if therefore electricity cause magnetism and mag- "netism cause electricity, why then electricity causes electri- "city, which becomes, so to speak, a *reductio ad absurdum* of "the doctrine." However electricity certainly does cause electricity by induction in bodies near it.

Mrs. Somerville writes in her above named work: "Dr. Far- "aday observes that such is the facility with which electricity "is evolved by the earth's magnetism, that scarce any piece of "metal can be moved in contact with others without a deve- "lopment of it, and consequently, among the arrangements of "steam engines and metallic machinery, curious electro-mag- "netic combinations probably exist, which have never yet been "noticed." Perhaps I may be excused for introducing here an extract from a letter addressed to the editor of a local paper as a curious specimen of terrestrial magnetic action:—

STEAM NAVIGATION.

Having noticed the extremes of propeller blades to be more subject to corrosion at their front than anywhere else, I have asked several profes-

sional gentlemen for an explanation, without however receiving a satisfactory answer.

It appears that the brass sheathing of the shaft, etc., in connection with the propeller, forms a closed circuit in the sense of the *British Association Experiment* (compare Deschanel's Natural Philosophy, by Professor Everett, London, 1873), and that *the electric currents* generated by the metal's rapid revolutions across *the field of force of terrestrial magnetism* have the tendency to escape by the most projecting points, which, in our case, are the propeller blades. Now, the nearest and most powerful conductor for electricity is the iron ship immediately in front of the blades, and "there appears to be no real exception to the rule that electricity, in "traversing an electrolyzable liquid, always produces its full equivalent of "decomposition."—(Ibid, page 646).

The "electrolyzable liquid" in this instance is water, which, being decomposed into its constituent elements, hydrogen and oxygen, will allow some of the latter to combine with the metallic surface of the electrode—(front of blade)—forming oxide, *i.e.*, corroding those parts of the blades in question.

The above may appear to many readers an idle speculation without a practical object, because the generation of electric and galvanic currents and their consequent chemical action cannot be prevented; but a means of escape more eligible to the current can be provided by a cylindrical circumference (like a hoop) of thin boiler plate, connecting or rather encircling the blades and projecting an inch or two towards the ship, the width of the ring to be decided by experience. The electricity would escape by means of this convenience, and would *corrode it instead of the propeller;* affording at the same time additional protection to the latter from fouling by ropes, fishing gear, etc.

Friends to whom I submitted the idea embodied in this extract objected to it as unpracticable; but the very screw propellor has been opposed by parties then considered competent, as impractical and objectionable, until practically introduced and approved.

FIRST APPENDIX TO "PERIODICAL CHANGE OF TERRESTRIAL MAGNETISM."

1.—*On the uature of Terrestrial Magnetic Poles.*

Some interesting information concerning Terrestrial Magnetism is contained in the introduction to Horsburgh's first volume of the India Directory, 6th edition, London, 1852. Captain Horsburgh says, page XVII:—"Mr. John Churchman, an Ameri-"can who was a member of the Imperial Academy of Sciences, "St. Petersburg, and Mr. Ralph Walker, the civil engineer, "formerly of Jamaica, appear to have published, nearly at the "same time, an ingenious hypothesis with a view of solving all "magnetical problems, relating both to the vertical and hori-

"zontal declination of the needle. In a diagram of the two "hemispheres on the plane of the equator, drawn by Mr. "Walker upon this principle, there are two magnetic poles re- "presented at different distances from the poles of the earth, "and revolving round the latter in unequal periods of time. "The north magnetic pole is placed for the year 1794 in lat. "71° N., long. 80 W.; the south magnetic pole in lat. 65° S., "long. 130 E., and by the intersections of the magnetic meri- "dians with the terrestrial meridians, the variation of the nee- "dle might be found by inspection on these hemispheres for all "places on the surface of the globe, were the positions of the "magnetic poles well ascertained and correctly laid down, and "the needle not subject to aberrations from various causes al- "ready mentioned.

"But exclusive of the perpetual aberration of the needle "from permanent causes of nature, it is likewise subject to ad- "ventitious and local attractions, liable to operate in a consid- "erable degree against the accuracy of any theoretical solu- "tions.

"Mr. Churchman supposes the periodical revolution of the "north magnetic pole round the North Pole of the earth to be "1,096 years; and the revolution of the south magnetic pole "round the south terrestrial pole to be 2,289 years, its motion "being much slower than that of the north magnetic pole, "which is the cause of perpetual irregularities of the variation "of the needle. He is of opinion that when one of the magne- "tic poles is in the zenith of any place, magnetic tides or great "inundations will there be experienced; and when the magne- "tic pole is far distant from any place, the sea will recede, and "alluvial land will be formed. Mr. Walker, besides his dia- "gram for showing the horizontal declination of the needle, has "drawn two hemispheres on the plane of the equator, for shew- "ing the vertical declination or dip of the needle for all places "on the globe; and in addition to his improvements on steer- "ing-compasses, he has invented a meridional compass for "shewing the quantity of variation by inspection at any time "of the day.

"The celebrated Dr. Halley was of opinion that the varia- "tion and dip of the needle could not be resolved consistently, "on the supposition of the earth having only one magnetic "axis and two magnetic poles; and he inferred that two mag- "netic poles must exist in the northern hemisphere, and two "also in the southern hemisphere of the earth, in order to ac- "count for the discordant magnetic changes.

"Professor Hausteen justly esteemed for his profound inves-
"tigations of magnetical phenomena and for his researches in
"Siberia and other places to ascertain the magnetic influence
"and intensity, has discovered the existence of a magnetic pole
"in that country, Siberia, which leaves no doubt that there are
"two magnetic poles in the northern hemispheres: and as the
"late expeditions of our enterprising navigators have proved
"the existence of another magnetic pole in lat. 70° 5½ N., long.
"96° 46¾ W., by the observations of Captain Jas. Clarke Ross,
"Dr. Halley's inference seems to have been correct, and may
"soon be demonstrated by similar researches in the southern
"hemisphere, where the existence of two magnetic poles will
"probably be discovered.

"According to the recent researches of Professor Hausteen,
"the earth has four magnetic poles, all revolving in the neigh-
"bourhood of the geographical poles; and the periods of these
"revolutions are respectively about 4,600, 1,740, 1,300 and 860
"years. These times, though long, as historical periods, are
"short compared with many of those cycles of which geological
"researches and astronomical calculations seem to prove the
"existence.

Müller-Pouillet informs us in his popular work on cosmic physics, that there are two foci of magnetic intensity in the northern hemisphere; one in northern Asia; and a stronger one in North America; but the magnetic poles where the inclination needle stands vertical and towards which the declination needle points, is not remarkable as a focus of greatest magnetic intensity.

In the Admiralty Manual for the deviation of the compass 3rd edition, London 1874, page 102, it is stated, "in the north-
"ern hemisphere there are two such foci; and it is believed
"there are two corresponding in the southern hemisphere.
"These foci of magnetic force are of unequal strength; in the
"northern hemisphere, the strongest or the American focus,
"lies to the S. W. of Hudson Bay near the great system of the
"North American lakes; the weaker or the Siberian focus may
"be assumed as in lat. 70° N., long. 120° E. In the southern
"hemisphere the position of the stronger focus may be assum-
"ed in lat. 70° S., long. 145° E., and the weaker is probably
"in lat. 50° S., long. 130° E."

Leaving out the probabilities and what is believed and what may be assumed concerning the southern hemisphere and dealing with the better established facts in the northern one only, the truth appears to be the following:—Hausteen, Halley,

Churchman, Walker and others by assuming more than one magnetic axis and more than two magnetic poles, have created a greater complication of the phenomenon than really exists, and trying to dissolve the mysteries of these self-created perplexities by elaborate calculations, they have arrived at more or less erroneous results.

I am confident if the cause of one of the magnetic foci in the northern hemisphere were to disappear suddenly, then what is now the magnetic north pole, would vanish just as suddenly and the remaining magnetic focus would become the magnetic north pole, for the following reasons: one magnetic focus prevents the needle from pointing in the direction of the other focus, but forces it in line with the diagonal of the parallelogram of magnetic forces towards the place designated as magnetic north pole; the same is the case with the inclination needle; each magnetic focus prevents it from being perpendicular at the other, and where it really does stand perpendicular, again is the magnetic north pole fixed by the parallelogram of forces of both magnetic foci. This magnetic pole naturally must be in line between the two foci of magnetic intensity, nearer to the stronger than to the weaker,—in this case, nearest to the American focus, which is in reality the case. From the preceding it will be seen that it hardly would be surprising, if earlier writers on this subject had assumed three magnetic axis, and half a dozen magnetic poles, rendering thereby the aspect of the whole phenomenon still more intricate. However the object of these lines is not to criticise my predecessors, but to advocate and of course submit to criticism my own views.

From a remark by General Sabini (Mrs. Somerville's Connection of Physical Sciences, Section XXX) it appears that Captain Ross has not been exactly at the magnetic north pole; "the spot where Captain Ross observed the needle so *nearly* "vertical in 1831 marks the approximate position of that loca- "lity at that epoch."

The fact is no doubt as I have stated, that the magnetic pole is no fixed spot of a certain small extension, but constantly fluctuating, of diurnal and secular change,—moving in an epicycloidal track round the geographical poles.

2.—*On the Nature of Foci of Terrestrial Magnetism.*

It will be recollected from the 4th Chapter of the essay on Periodical Change that by the combined efforts of the earth's re-

volution and the attraction of the sun upon the earth's protuberance at the equator (owing to our planets spheroidical shape) an elliptic current round the terrestrial magnetic nucleus was supposed to be created which, if seen from the magnetic equator, would represent a flat oval figure with its greater length in the direction of magnetic axis; if viewed from the magnetic north pole it would also represent an oval shape, the thinner end towards the axis of the earth's rotation; the whole perhaps would have a somewhat twisted appearance, owing to the fact, that during the winter solstice the nutatory circulation current would be accelerated in the northern hemisphere, on account of the sun's greater attraction in perihelion, tending to elevate more the northern half of the axis of rotation at a right angle with the plane of the ecliptic, than the southern half during the summer solstice, because of the sun's lesser attraction in aphelion. This would indeed let it appear possible that the northern magnetic pole might revolve faster round the globe than the southern one, as Mr. Walker and others seem to have supposed.

The foci of the ecliptic current as viewed from the North Pole would in all probability be corresponding to the foci of Terrestrial Magnetism upon the surface of the northern hemisphere. This idea receives confirmation, if we inspect the charts by Captain Duperrey, of the French Navy, in which he lays down in horizontal projection the isodynamic lines round the point of intersection of the meridian of Paris with the parallels of 60° N. and S. latitudes; the same idea is conveyed by the inspection of the charts of the magnetic meridians and parallel curves in polar projection by the same officer; and since from the preceeding chapter we have seen that the magnetic axis of the earth depends upon the relative positions of the magnetic foci to one another, then it will become more easy to understand how the apparent irregular fluctuations of diurnal variation are brought about; the sun and moon passing together or separately once over the astronomical meridian of every individual focus of intensity, and once over the meridian 180° distant from it, would cause one lunar and one solar subterranean tide wave to pass twice in 24 hours over every one of the four supposed magnetic foci, except of course at spring tides, when lunar and solar tides become united into one, each tide wave would alter to a certain extent the momentary position of the respective focus, and would thereby affect the direction of the magnetic axis and of course the position of the magnetic pole, consequently also the variation of the needle. This theory would

account better for the changes of diurnal variation, than the resemblance of the isothermal curves with the isodynamic ones, because the former can be considered stationary for our purpose, while the latter do change. If it could be proved impossible to admit the quotidian displacement of our planets magnetic nucleus (by the sun's and moon's attraction), causing an independent circular motion of the same as pointed out in Chapter V of Periodical Change, then perhaps the idea demonstrated in this present chapter may also be found sufficient to account for all phenomena of diurnal variation; but considering that our whole globe is constantly kept off its mean orbit round the sun by gravitation and since it is consequently not the centre of the earth, which describes the mean orbit round the sun, but a certain point, which is the centre of gravity between earth and moon combined together (making the real track of the earth resemble the pitch of a screw propeller through the water), I believe it indeed possible, that the solid nucleus in the fluid interior of the earth under the influence of gravitation towards sun and moon may have an independent motion as described in Chapter V.

Could we from a magnetic focus on the surface of the earth see the currents of the interior, I think it likely that a rotatory motion would be noticed at each focus round an axis, connecting the focus in question with the corresponding one in the opposite hemisphere, and in the same direction, as the main circulatory current, with the sun.

8.—*On the present shape of the Agonic Lines.*

The simple relation between magnetic focus and pole as demonstrated, and its effect upon the magnetic needle is interfered with by two principal causes, if we disregard possible local attraction of Continents, thermal-electricity, &c., supposed by many competent authorities to influence the variation.

The first principal cause producing, what may be called a deviation of the declination needle from the magnetic meridian is best illustrated by the oasis of Western variation in China and Japan, and caused by the occurrence of the Siberian focus to the Northward and Westward of it; magnetic attraction, like gravitation, increases inversely, as the square of distance decreases, and the Siberian focus being nearer than either pole or other focus, it naturally deflects the North end of the needle in all places within this oasis of Western declination to the

Westward; and again places in the Northern hemisphere immediately to the Westward of this oasis (which indeed ought to have Westerly variation, if the needle were allowed to point to the Magnetic North Pole), shew Easterly variation, because the nearest focus of magnetic intensity (the Siberian one) is to the Northward and Eastward of them. Now supposing the system of magnetic lines to revolve with the magnetic poles from East to West, this repeated change of secular variation from West to East and *vice versâ*, several times over again at the places in the track of this peculiar insula of Western variation would make upon an observer the fallacious impression, that the Magnetic North Pole were moving occasionally in opposite directions; but in fact it proves only, how the plurality of magnetic foci may cause contradictory irregularities in the arrangement of Isogonic lines.

The second principal cause of deviation of the needle from the direction towards the nearest magnetic pole is the existence of the second magnetic pole in the other hemisphere, tending to draw the opposite end of the needle towards itself, to make it parallel with the magnetic axis, *which coincides nowhere* with the axis of the earth; this is well shewn by the shape of the Agonic line passing through America; the difference of longitude between the North and South Pole across the Pacific being only about 110°, the South end of the needle anywhere to the Southward of the Magnetic North Pole and near its meridian having the Magnetic South Pole at its left (when looking towards the centre of the earth), is drawn in that direction, the more, the further to the Southward, and as a matter of course the North end of the needle deviates just as much to the right, or the Eastward, causing the whole Agonic line in that part of the world to encroach upon certain regions of our globe, which otherwise would have Westerly variation; the same effect of the South Pole upon the needle's South end can be proved along the Southern part of the Agonic line passing through Australia; the meridians of the two Magnetic Poles across the Pacific again are only 110° of longitude apart, but *viâ* the Indian Ocean and the Atlantic they are about 250° difference of longitude apart; the consequence is, that the South end of the needle is drawn in the nearest direction towards the Magnetic South Pole, in this case to the right, or Eastward; the North end of the needle must deviate just as much to the left, or Westward, causing in the Southern hemisphere an inroad of Westerly variation into regions, where otherwise *Easterly* variation ought to be.

Assuming, that Hausteen and Walker were correct in letting the Magnetic North Pole revolve faster than the Southern one, then during one revolution, the former would be once on the meridian of the latter, and once 180° from it; in both cases the geographical meridian would coincide with the line of no variation, and the Eastern and Western variations would be equally divided, as stated in a previous chapter. These supposed unequal motions of the two magnetic poles would cause alternately contortions and distortions of the magnetic axis, and then periodical changes of the geographical latitude of the magnetic poles might presumably also take place.

4.—*Tidal Motion and Diurnal Variation.*

In order to form an idea how the position of the magnetic foci and poles may be affected by the influence of subterranean tidal movements, besides the mere perpendicular tide wave, it is necessary to have before our mental eyes clearly our knowledge of oceanic tide waves, because it is reasonable to suppose that the one must behave analogue to the other.

It is not my intention to reproduce in this chapter what may be read in every good work on tides; but I wish to draw attention to a fact which appears to have been overlooked at least by those writers, whose works I have had an opportunity to consult; I cannot illustrate better what I mean than by making a few extracts from a couple of nautical works. First from the China Sea Directory, Vol. III, 1874, page 350 and 351:—

"The tidal streams at the entrances of the Yangtsze from "Gutzlaff to Shaweishan rotate, performing one revolution "(with the sun) in 12 hours. To the southward of Gutzlaff "the tides are also rotatory, but not with that regularity which "is observed about the Amherst Rocks. There is also reason "to believe, although the fact has not yet been conclusively "established, that they preserve the same character some dist-"ance to seaward, and far to the northward. During its revo-"lution the direction of the stream changes about two points "every hour, excepting when veering from N. W. to N. E. "about the time of high water, and from S. E. to S. W. about "the time of low water, when the change is more rapid. The "northern stream for the most part makes and completes the "flood, and the southern stream for the most part makes and "completes the ebb, although the first part of the flood is made

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"by the southern stream, and the first part of the ebb by the "northern, called sometimes "tide and half tide."

"Mr. G. B. F. Swain, master of H. M. S. *Pilot*, 1850, states "that the revolving tide has been noticed as far out as the Sad- "dle Islands, whilst others assert that the stream when fully "made sets N. W. by W. and S. E. by E. These statements "are not contradictory. Lieut. C. Bullock, R.N., found the "tides to rotate, 120 miles north of the entrance, at 70 miles "from the land."

Captain Horsburgh gives in his India Directory, Vol. I, page 599, the following table concerning tidal motions off the river Hoogly, when uninfluenced by the wind:—

"1st quarter	flood	N. W. by W.
"2nd ,,	,,	N. N. W.
"3rd ,,	,,	N. N. E.
"Last ,,	,,	E. N. E.
"1st quarter	ebb	S. E. by E.
"2nd ,,	,,	S. S. E.
"3rd ,,	,,	S. by W.
"Last ,,	,,	S. W. and W. S. W."

This is a complete revolution (with the sun), in the bay of Bengal, the same as off the Yangtsze.

Lately I have heard that "divers" engaged in salving operations in the vicinity of the Lammock Islands (Formosa Channel), have also observed a rotation of tides in that locality. From personal experience I am able to add the following fact:

In the summer of 1874, when commanding the British barque *Charley* of Hongkong, I was becalmed for several days during a voyage from Japan to Shanghai; to judge by the lead, the currents appeared very unsteady, setting at different times in different directions. I had good observations and found that I was drifting away towards the Strait of Corea, which set I attributed to part of the Japan stream (Kurosiwo current), branching off in that direction; determined not to lose more ground than could be helped, I brought up with the stream anchor on the great Yangtsze bank, about half way between Quelpart and the Saddle Islands in 23 fathoms. Remaining there some time for want of wind, I was much surprised to find the tides rotate with the same regularity as off the Yangtsze (with the sun), which accounted for the seeming irregularities of currents, indicated when consulting soundings only.

By these facts I am led to believe that tidal motion (if not

interferred with by the shape of neighbouring continents and Islands or Galese), in the northern hemisphere always takes place from north, through east by south and west; in the southern hemisphere of course in the opposite direction; to verify this latter supposition the information contained in the 7th edition of Horsburgh is not sufficient; generally the establishment of the port and the rise and fall are only given for most places in the southern hemisphere; but I am confirmed in my opinion by much, what Horsburgh relates of equatorial regions. In the second volume of the India Directory he says on page 759 about Sourabaya Strait:—"Ships are sometimes "detained upon the bank, or at the entrance of the channel, "by the singular tides which prevail there, and for which "science has not yet been able to account, or the pilots even to "reduce to rule. In the chart of the channels leading to Sou- "rabaya, by Lieut. M. H. Jansen, D.R.N., the depths are "given at low water, and the following remarks are made on "the tides:—"During the months in which the sun is on or "near the equator, *i. e.*, in March, April, September and Oc- "tober, there are in this channel, at the full and change, two "tides in 24 hours; but at the quarter moon's, as well as dur- "ing all the other months, there is only one tide, and it makes "low water in the night with south declination, and in the day "when the sun has north declination.

"The greatest rise and fall of spring tides is 6 feet, and it "occurs only in those months when there is but one high "water in the 24 hours, and 3 or 4 days after full and change. "The least rise and fall is 4 feet, and this takes place at the "full and change also, but only in the months when there are "the two tides, which may be regarded as a change for the "day-high-water to the night-high-water, and vice versa. At "the quarter moons of these months the water rises 5 feet, and "in every other month 5½ feet above the depths marked in this "chart.

"In the month of May it is high water between 21½ h. and "0½ h.; June, 20 h. and 0½ h.; July, 19 h. and 0 h.; August, "16 h. and 0 h.; November, 10 h. and 12½ h.; December, 8 h. "and 12 h.; January, 8 h. and 12 h.; February, 7 h. and 12 h.

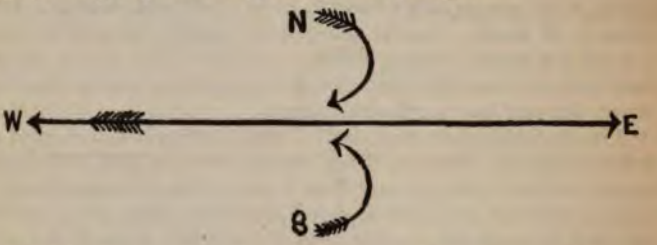
"At the spring tides, as well as at the quarter moons, it is "high water always at 10½ h. or 22½ h.

"During the months when the two tides occur, it is also "high water at 10½ h. and 22½ h. These two tides are, how- "ever, different in height; and when the sun's declination is "north, the morning tide is the highest; but when it is south,

"the evening tide. In those the quarters which give but one "tide,(1) give the higher water as at full and change."

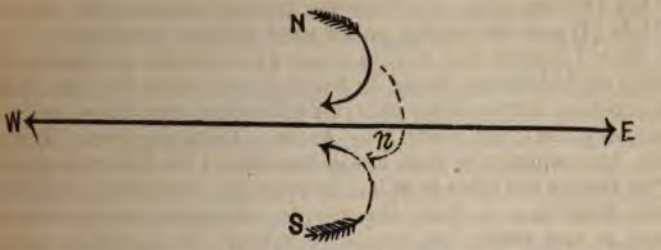
Now I believe that during the sun's northern declination the tides in Sourabaya Strait do rotate the opposite way, as off the Yangtsze; during his southern declination the tides are also rotatory, but the same way as the Yangtsze tides. During the two equinoxes then it will be difficult for local pilots even "to reduce the tides to rule," because the tides changing from one rotation *i. e.* with the sun, to the other, *i. e.* against the sun, or vice versa, may appear to become to a certain extent confused and irregular.

I will not transgress too much by recording more instances of apparently irregular tides, as I could; but refer for one remarkable instance more to page 737 of the same volume of Horsburgh's, concerning Pitt Strait, where several vessels by the tides setting consecutively in "all directions" running considerable danger: I believe, if they could have anchored they would, (as I did on the Yangtsze bank in 1874) have experienced a rotary regular tide, perhaps at springs:—



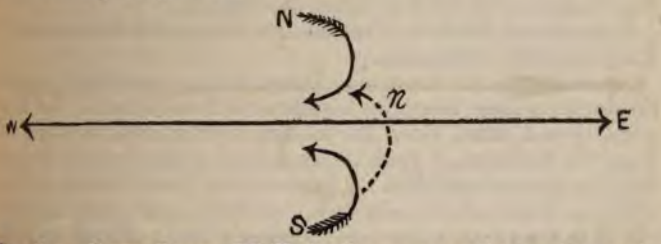
W E is the equator, the curved arrow N indicates the rotation of tides in the northern hemisphere, the curved arrow S shews the same in the southern hemisphere; supposing the strait arrow at W to point out the direction of the flood tide on or near the equator, then the flood and ebb currents will occur at the same time on both sides of the equator, and places near it will have two regular tidal revolutions in 24 hours. At neaps the flood wave resulting from the moon's lower meridian passage becomes so much counteracted by the sun in quadrature, that it is scarcely noticeable, or incapable to overcome the *vis inertiæ* of tidal motion, resulting from the moon's upper meridian passage; then places like Sourabaya Strait will only experience one flood and one ebb in 24 hours.

(1) Horsburgh's tidal account of Banca Strait resembles in many points that given of Sourabaya Strait.



During the sun's southern declination the northern currents stretches over across the equator and arrives retarded at N, continuing the southern already finished flood stream for another 6 hours; a singular phenomenon occurs with the ebb stream, thereby allowing only the effects of the upper meridian passage to appear as one flood and one ebb in 24 hours.

The seeming irregularities of tides must be greatly increased by the circumstance of the principal factor in their production, *i. e.* the moon, crossing and recrossing the equator so many times during the year:—



In the above figure W E is the equator during the sun's northern declination; the stream from the southern hemisphere crosses the equator to the northward in the direction of the curved arrow S N and continues the spent tidal movement in the northern hemisphere similarly as in the preceding case; the consequence is the same; one complete tidal rotation in 24 hours only.

If this view of oceanic tidal motion can be accepted, then it is natural to suppose that the earth's internal fiery ocean must be equally or rather more so affected; being as many miles perhaps in depth, as the briny outside ocean is fathoms only: and then it would be easily understood that the magnetic foci and poles by being carried along with the tidal motion would cause a change of the magnetic axis in the same manner, as if the earth's magnetic nucleus were moving, as described in a

previous chapter; tidal motion or displacement of magnetic nucleus would have the same effect: change of axis of our planets magnetic internal apparatus, and thereby producing the main features of annual and diurnal variation, many seeming irregularities being the result of the unsymetric distribution of magnetic foci and poles, and the consequent eccentricity of magnetic axis. My attention has been called to Humboldt's Kosmos, vol. IV, Stuttgart and Tübingen, 1858 (" Specielle Ergebnisse der Beobachtung in dem Gebiete tellurischer Erscheinungen "), in which much valuable information is contained concerning Terrestrial Magnetism.

Humboldt states (p. 53) that the Chinese, Indian, Arabian, and Malay navigators knew the magnetic variation before Columbus; in fact Andrea Bianca had entered it on his sea charts in 1436; what Columbus did discover is the line of no variation, passing then $2\frac{1}{2}°$ east of the Azoric Island, Corvo, and I think what the Spanish savants, according to Commander Walker, refused to credit, may have been Columbus' statement, that to the westward of his newly discovered line of no variation the variation were opposite (westerly) to what at his time it must have been in Spain (easterly.)

Commander Walker gives as his source of information the Encyclopaedia Britannica.

According to the Kosmos it seems, that generally all magnetic elements have two daily maxima and two minima; for fuller particulars I must refer the reader to Humboldt's work; on page 97, however, I find it mentioned according to Sabine, that the diurnal variation of intensity at Van Dieman's Land (Hobart Town) shews only one maximum and one minimum per diem; and referring to Horsburgh's India Directory, Vol. II, page 839, I find the following tidal information about d'Entrecasteaux Channel (Van Dieman's Land): " the rise of the " tide *which flowed only once* in 24 hours was about 6 feet per- " pendicular; high water from 9 to 12 hours at full and change, etc;" this is a remarkable coincidence with only one daily maximum and one minimum of magnetic intensity, which I consider may be a proof of also one subterraneous tidal revolution only in 24 hours.(2)

(2) Humboldt on page 84 (Kosmos, Vol. IV.) calls attention to a zone of weak intensity between the northern and southern magnetic hemispheres, which alternately shares the magnetic movements of the opposite hemispheres during opposite seasons, similar as I suppose a corresponding zone in the same regions, partaking alternately of the tidal rotation of each hemisphere, as governed by the declination of the sun.

Humboldt asks (on page 141) if the line of no variation, which Columbus found near the Azores in 1492 is the same that Davis and Kieling in 1607 found at the Cape of Good Hope? I think not; Columbus's Azoric line must be the one, which now passes through the sea of Ochotsk, the Kurile Islands and to the eastward of Japan; and Davis's and Kieling's line must be the one, which Müller and Pouillet in 1663 passed through Paris (according to Picard in 1666), and which runs now through North America and the South Atlantic.

According to Graham (the same volume of the Kosmos, page 189, Philos. Trans. for 1724-25), the variation of declination depends "neither upon heat nor cold, dry or moist air. The "variation is greatest between 12 and 4 in the afternoon, and "the least at 6 or 7 in the evening." To this Humboldt makes the remark "es sind freilich nicht die wahren wendestunden," "(but these are not the true turning hours"); I believe Humboldt is wronging Graham, who for his time may have given the true turning hours correctly, which may change with the revolving position of the magnetic poles.

In more than one place Humboldt states his opinion that temperature has nothing to do with periodical variation, and on page 192 he quotes Relshuber (translated as follows:)— "there are two maxima and two minima of declination in 24 "hours, but only one maximum and one minimum of temper- "ature." At pages 176 and 177 Humboldt quotes from Sa- "bine:—"The turning periods of the year are not, as many "might be supposed to anticipate, those months in which the "temperature at the surface of our planet, or of the subsoil, or "of the atmosphere attains its maximum and minimum. The "annual variation is obviously connected with and depend- "ent on the earth's position in its orbit relatively to the sun, "around which it revolves; as the diurnal variation is con- "nected with and dependent on the rotation of the earth on "its axis. It is a remarkable fact, which has been estab- "lished, that the magnetic force is greater in both hemispheres "in the month of December, January and February, when the "sun is nearest to the earth, than in those of May, June and "July, when he is most distant from it; whereas if the effects "were due to temperature, the two hemispheres should be op- "positely instead of similarly effected in each of the two pe- "riods referred to.

From page 82 the following is a translation:—"The princi- "pal result of researches on the magnetic influence of the "earth's satellite, which according to Melloni, only shews a

"trace of heat generation, is that the magnetic declination "upon our earth in the course of a lunar day suffers a regular "change, arriving twice at a maximum and twice at a mini- "mum. If the moon, says Kreil very properly, produce no "change of temperature upon the surface of the earth, recog- "nisable by common thermometers, then she can produce no "alteration of Terrestrial Magnetism by this means; if in spite "of this such an influence is observed, it must be concluded, "that it is "brought about by other means, than heat." This other means, I repeat it, can only be the same, which produces oceanic tides.

Humboldt says on page 189 (translation): "compare extracts "of a letter from me to Karsten, Rome, 22nd June 1805, *on* "4 *motions* of the magnetic needle, comparable to 4 magnetic "ebb and flood tides, analogue to the barometric periods, etc."

A proof that during perihelion motion and commotion in the interior of the earth by the greater attraction of the sun must increase, is the rise of temperature in the Schergin shaft of Siberia, sunk 382 Parisian feet into the frozen ground; I translate the following from page 168:—"A remarkable and hi- "therto unexplained phenomenon is the rise of temperature, "which in winter sometimes has been noticed in the deeper "parts only, without any traceable influence from the outside."

Since the sun's greater attraction during perihelion accelerates the motion of the earth in its orbit, why should it not also increase the velocity (intensity) of the subterraneous circulatory current? and since greater motion in the earth's interior must manifest itself by a greater production of heat, we have an explanation of the phenomenon in the Schergin shaft: a translation (transformation) of the sun's greater attraction during perihelion into heat. Another direct proof of increased internal motion during perihelion. I translate from page 296: "The activity of the "Stromboll," (volcanse) is like that of the "Aetna, greatest in November and during the winter months,' *i. e.* during perihelion.

Humboldt states on page 488 that Poisson, with whom he conversed several times about subterraneous tides, thought them to be inconsiderable, and Humboldt's astronomical friend Dr. Brünnout expressed himself that internal tides could just as little take place on account of our planet's solid crust, as in the ocean, if the latter were covered with an unbreakable sheet of ice; but Ampere said that owing to the action of the moon on the enormous internal liquid mass, tides would result analogue to those of our seas, but much more terrible ("mais bien

"autrement terribles"), on account of the larger extent and greater density of the mass, it would be difficult to conceive how the shell of the earth could resist, being constantly battered by a kind of hydraulic ballista ("etant incessamment "battue par une espèce de bélier hydraulique (?) de 1400 lieues "de profondeur").

To these various ideas I can only again repeat from Mr. Kingsmill's Border Land of Geology and History, page 5:

"If the interior of the earth were liquid and its crust composed "of so rigid a material as steel, and 800 miles thick, it would "yield to the deforming influences of centrifugal force and the "attraction of the sun and moon as if it were india-rubber."

Considering all, it seems that opinions on those subjects differ widely; or to use a German proverb: "Darüber sind die "Gelehrten noch nicht einig."

To my mind there remains, no doubt, that the force of those celestial bodies which cause the nutation of our planets' axis of rotation and the precession of the equinoctial points, also do cause in the movable fluid interior of the earth those movements, which I have endeavoured approximately to picture.

Biot, Hausteen and others appear to have the idea of a magnetic nucleus before me; Humboldt objects strongly to Halley's views on this subject, but Halley placed his nucleus in a hollow terrestrial shell, while I take the *dense* state of our planets' interior into due account (see Bohn's edition of Humboldt's Cosmos, Vol. I, p. 168). Adhémar states concerning Bertrand of Hamburg: "Il supposait, que la terre était creuse "et qu'il y avait dans son interieur un gros noyau d'aimant," etc. (Croll's Climate and Time, p. 548.) I was unacquainted with these elder ideas, when I occupied myself first with the same question.

Note.—In Amadée Guillemin's "The Heavens," edited by Norman Lockyer and revised by Richard A. Proctor, the latter gentleman writes on page 391, after the current and generally accepted explanation of tidal phenomena is given: "It must "be noted, however, that although the statistical equilibrium "of a tidal wave is thus accounted for, the dynamical condi-"tions of the problem cannot be thus explained. On the con-"trary, if we consider only the dynamical rotations, we shall "find that the place of low water should be under the moon "and at the opposite part of the earth, the place of highwater "between these regions. Newton, Laplace, Airy and others "agree in this view. The theory of the tides remains yet to be "established satisfactorily. Much that has been presented in

"popular treatises as part of this theory is in reality but an "account of the results of observation.

"On the 1st of September, 1859 two astronomers, Messrs. "Carrington and Hodgson, were independently observing a "spot, when they noticed a very bright star of light suddenly "break out over it, moving with great velocity over the sun's "surface. At the same moment the magnetograph at Kew, "where all the changes in the earth's magnetism unceasingly "register themselves, was violently affected."—(Amadée Guillemin's "The Heavens," London, M, DCCC, LXXVI, page 52.)

5.—*Possible Origin of Magnetism.*

To understand the nature of magnetism, it is essential to recollect that more substances than iron, steel, nickel, cobalt and so forth, are magnetic.

Sir W. S. Harris, in his paper on the transient magnetic state of which various substances are susceptible has given the following table of the comparative magnetic inductive susceptibility of the following substances:—

Metals, &c.	Rolled Silver.	Rolled Copper.	Cast Copper.	Rolled Gold.	Cast Zinc.	Cast Tin.	Cast Lead.	Solid Mercury.	Fluid Mercury.	Cast Antimony.	Cast Bismuth.	Glass.	Marble.	Mahogany.	Water.
Comparative magnetic energy ..	30	29	20	16	10	6·9	3·7	2	1	1·3	⅔	0·35	0 37	0·37	0.27

Sir W. S. Harris found that by condensing the metals their magnetic energy was increased (Commander W. Walker's repeatedly quoted work "The Magnetism of Ships," page 17). From this table it will be seen that solid (which can only mean frozen) mercury is 100 per cent more capable of magnetism than the fluid mercury; but in solid mercury the molecules must be closed together than in the fluid, because the former comprises a smaller compass than the latter, and since we know that the attraction of bodies increases inversely as the square of the distance decreases, what possible reason could there be to suppose that the attraction between molecules should not increase at the same rate, should not obey the same law, if the body which they constitute does contract; in other words, when they are brought nearer to one another within the body? Now, if under ordinary circumstances this special

form of gravitation, the molecular affinity, is sufficient to keep the bodies together in their ordinary aggregate state, what must be the consequence, if by excessive pressure or by contraction a surplus of affinity is created more than is required for the existence of the body under ordinary circumstances? Nothing is more natural than that this surplus of disengaged affinity should make its presence known under some form or other, for instance, as magnetism; this is therefore an explanation for the increased magnetic capacity in solidified mercury. We may then say: by increased density of bodies magnetism is generated; iron is an instance when by some mechanical process (external superior force) converted into the denser steel.

If a magnet is heated, magnetism is lost, because it must be reconverted into original affinity to counteract the increasing centrifugal heat vibrations of the molecules.

In soft iron (says Mr. Merrifield in his severally cited work "Magnetism, etc., page 29) "where the magnetism must be "induced, the power increases with a rise of temperature to a "blood red heat. With other magnetical substances, as co- "balt and nickel, the effects of heat vary; and Faraday shewed "that some substances which at ordinary temperatures are not "magnetic, become so when exposed to intense cold."

This case of iron becoming more capable of magnetism until heated to a certain degree is one of those exceptions which proverbally prove rules; for Tyndall states in "The Forms of "Water," page 124: "Water is not a solitary exception to an "otherwise general law. Heat expands, cold contracts, there "are other molecules than those of this liquid which require "more room in the solid crystalline condition than in the ad- "jacent molten condition. Iron is a case in point. Solid iron "floats upon molten iron exactly as ice floats upon water. "Bismuth is a still more impressive case, and we could shiver "a bomb as certainly by the solidification of bismuth as by "that of water." This shews that iron passing from the solid to the molten state at certain degrees of heat must be contracting, thereby disengaging a certain amount of molecular affinity, manifesting itself as increased magnetic capacity. Having these facts (which I cannot express better than saying that by increased density of bodies capable of magnetism a certain amount of spare affinity must appear under the form of magnetism), vividly before our eyes, then it will easily be understood how terrestrial magnetism originated, if we throw a hurried glance at the earliest history of our planet.

"Supposing with Helmholtz that the sun originally existed "as a nebulous mass, filling the entire space presently occu- "pied by the solar system and extending into space indefinite- "ly beyond the outermost planet."—(Croll's Climate and Time, page 848.)

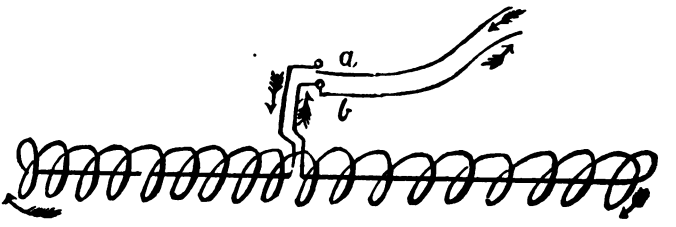
And supposing this nebulous matter sufficiently contracted, that at the outer limit or surface, mass after mass had detached itself from the parent body, forming successively the outer planets with their satellites, until our own planet was formed.

Suppose x million of years ago the diameter of the earth's body had been 10,000,000 miles, and the attraction betweenf two neighbouring molecules=m, then y millions of years afterwards the diameter having contracted to 100,000 miles, the attraction between two neighbouring molecules must have been 100^2m, or 10,000 times greater; part of this increased power of gravitation must have manifested itself as telluric magnetism, the rest being radiated into space as heat.

It will be seen that I am trying to trace magnetism home to gravitation; in the following chapter some more weighty reasons will be produced to support this view; at present a few remarks concerning the analogy between magnetism and electricity may not be out of place.

This essay not being intended for a lesson in elementary physics, the reader is supposed to be sufficiently conversant with the action of electricity upon magnets, or of magnets upon electric currents, to understand the following deduction; but being unable to express better what I should expound first, to make the succeeding argument clearly understood, then it can be found in "Natural Philosophy," translated and edited from Ganot's Cours Elementaire de Physique, by E. Atkinson, Ph.D., F.C.S., 2nd edition, page 501.

"Structure of a solenoid.—A solenoid is a system of equal "and parellel circular currents formed of the same pieces of "covered copper wire, and coiled in the form of a helix or spi- "ral, as represented in the accompanying figure:—



"A solenoid, however, is only complete when part of the wire "passes in the direction of the axis in the interior of the helix.

"With this arrangement, when the circuit is suspended in "the mercury cups of the apparatus, and a current is passed "through, it is directed by the earth exactly as if it were a "magnetic needle. If the solenoid be removed it will, after a "few oscillations return, so that its axis is in the magnetic "meridian. Further it will be found that in the lower half of "the coils, of which the solenoid consists, the direction of the "current is from east to west; in other words the current is "descending on that side of the coil turned towards the east, "and ascending on the west. In this experiment the solenoid "is directed like a magnetic needle, and the north pole, as in "magnets, is that end which points towards the north, and the "south pole that which points towards the south."

"Mutual actions of magnets and solenoids.—Exactly the "same phenomena of attraction and repulsion exists between "solenoids and magnets as between magnets. For if to a "movable solenoid traversed by a current, one of the poles of a "magnet be presented, attraction or repulsion will take place, "according as the poles of the magnet and of the solenoid are "of contrary, or of the same name. The same phenomena "take place when a solenoid, traversed by a current and held "in the hand, is presented to a movable magnetic needle. "Hence the law of attractions and repulsions applies exactly "to the case of the mutual action of solenoids and of magnets,"

"Mutual actions of solenoids.—When two solenoids traver-"sed by a powerful current are allowed to act on each other, "one of them being held in the hand, and the other being "movable about a vertical axis, attraction and repulsion will "take place, just as in the case of two magnets. These phe-"nomena are readily explained by reference to what has been "said about the mutual actions of the currents, bearing in "mind the direction of the currents in the ends presented to "each other."

Now, if a house in all main features resembles a certain other building, both answering exactly the same purposes, then the second building must also be a house, though perhaps of another style of architecture and of different material; both must be constructed after a similar plan.

In the solenoid we see that a current traverses a wire in one direction and is conducted back spirally outside the wire beyond the opposite end, and led back again inside the spiral coil in the original direction.

each other, to form *one* continuous current; in both cases the magnetic currents obey the law to arrange themselves parallel to one another; even in the second case, where they have the tendency to form *one* straight line, because it cannot be denied that a straight line is parallel to itself.

The attentive reader will readily observe that by this simple theory all phenomena peculiar to magnets, without a single exception, can be satisfactorily accounted for, not having recourse to Ampère's somewhat complicated artificial theory and the hypothetical two fluids: Austral and Boreal.

According to this hypothesis the earth itself would be only the vehicle of a vast magnetic current, emanating in the antarctic regions and visible under favourable circumstances as Aurora Australis, spreading towards the equator and thence converging in regular curves towards the arctic regions, where frequently visible as Aurora Borealis. It would make no difference if the current were travelling in the opposite direction; I have only assumed the former circulation, because the southern hemisphere is believed to possess more magnetic intensity, some of which might be spent by the current's passage to the northward in meteorological phenomena (thunderstorms, etc.)

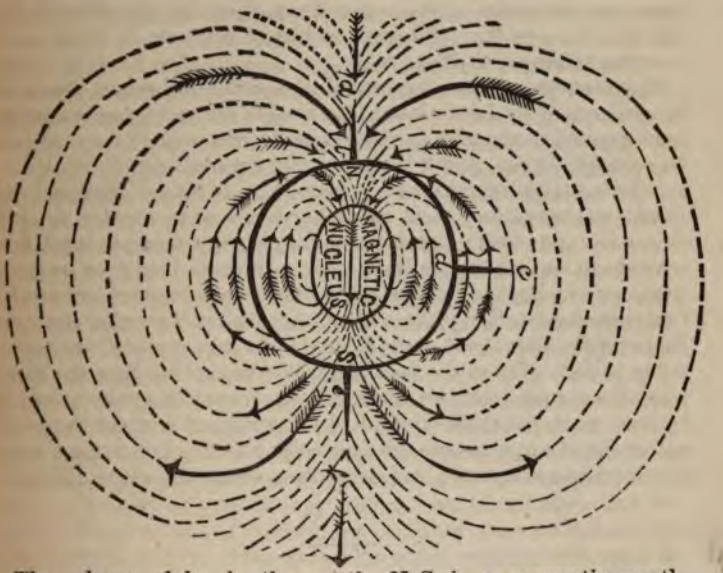
A tangent on either magnetic current curve in any place would probably be identic with the magnetic dip; might this magnetic current be the cause of atmospheric electricity and the returning current (through the earth) the cause of telluric electricity?

"Many hypothesis have been propounded to explain the ori-
"gin of the atmospheric electricity. Some have ascribed it to
"be the friction of the air against the ground, some to the
"vegetation of plants, or the evaporation of water. Some
"again have compared the earth to a vast Voltaic pile, and
"others to a thermo-electrical apparatus. Many of these
"causes may, in fact, concur in producing the phenomena."
—(Ganot's Cours élémentaire de Physique, by E. Atkinson, London, 1875, page 463.)

It would be interesting to know whether the motion of the earth's interior might be contributing to produce electricity; is it possible that the secular motion, the rotatory current and tidal action of our planets' fluid interior may produce electric currents, perhaps from east to west, according to Ampère's opinion?

The northern and southern lights probably are occurring in the highest parts of the atmospere, where it begins to become very rarified, in analogy of the electric light in vacuo, or rari-

fied vapours (compare Ganot's Natural Phylosophy, etc., etc.) page 525-526.



The above globe is the earth, N S is a magnetic north and south line; magnetic ethereal matter emanates in the southern hemisphere, probably in decentric undulations (from common centres), crosses the equator in the direction of the arrows and enters the northern hemisphere, probably in accentric undulations (towards common centres), to circulate back again through the body of the earth towards the antarctic regions, and so forth; *a b*, *c d* and *e f* represent iron masts at the poles and at the equator; they are traversed by magnetic induced currents, parallel to the nearest curves in the direction of the arrows; in the northern hemisphere *a* is the induced south pole; *b* the induced north pole of *a b*; in the southern hemisphere, *e* is a south pole and *f* a north pole of *e f* by induction from the earth; at the magnetic equator the induced magnetic current must be horizontally somewhere between *c* and *d*, like the arrow.

The arrows indicate the supposed direction of this magnetic current; the arrow heads present everywhere that end of the magnetic needle, which *on the surface of the earth is the north seeking pole.*

The tendency of all magnets below and above the surface of the earth must be to remain parrallel to this terrestrial magnetic circulation, and if there were a tunnel throngh the earth from one magnetic pole to the other, then the direction of the needle at the *centre of the earth* would be opposite to what it is on the surface near the equator.

The reason of the terrestrial magnetic influence being so great in soft iron is no doubt due to this metal's great capacity for atomic polarity (compare Tyndall's "Atomic Poles" in the "*Forms of Water*," p. 32) the molecules arranging and disarranging themselves instantaneously, according to prevailing magnetic or electric currents; steel being harder, the molecules do not so easily give way; but when arranged in a manner most favourable to a current's passage, they are more likely to remain so (Coercive Force.) Consequent points in a magnet are due to faulty magnetisation; the bar being touched wrongly, currents in opposite directions are formed and consequently intermediate poles. When the pole of a weak magnet touches the same pole of a strong one, the current in the former may be reversed by the more powerful current of the stronger magnet in an opposite direction, and therefore also the poles of the weaker magnet would be reversed; lightning may cause the same effect.

6.—*On the Coincidence of Periodical Maxima and Minima of Solar Spots with similar changes of Terrestrial Magnetic Variation.*

It is a fact well established by the labours of Schwabe, Wolf and others that in mean periods of about eleven years the number and size of solar spots are subject to gradual changes; while Sabine, Hornstein and Lammont very early discovered a parallelism between these changes and similar ones of the terrestrial magnetic elements; both increase during about $5\frac{1}{2}$ years, when they attain their maxima and then decrease again until they attain their minima together; therefore it has been supposed by many competent authorities that terrestrial magnetism must be influenced by a maximum or minimum of solar spots. I think it more likely, that both phenomena are independent of one another, but since they do coincide, that they must be caused by the same means, for the following reasons: Considering solar spots first, we must bear in mind that the sun

is a fiery mass in the process of cooling, the same as the earth has been in former ages. The spots are products of this cooling process, partly in the solar atmosphere (solar vapours composed of various elements condensed to solar clouds); partly floating on the surface like floes of ice upon water; or in the case of the earth's earlier age, like what then must have been the first nuclei of the forming solid crust (now primary rocks?); these slakes given, they may burst by contraction, the fiery liquid springing up between the pieces, separating and flooding them, or the pieces perhaps may sink into the fiery deep below and become melted again, after which the radiation of heat into space (temporarily suppressed by the intervening spots), will be renewed with increased force. But it would be out of place to discuss here the various theories of solar spots; my object only is to remind that they are a product of a cooling process upon the sun; this cooling process can solely occur by radiation of heat from the sun's surface into space; therefore, if this process appears enhanced during about $5\frac{1}{2}$ years, it is a direct proof that during this period the sun gradually becomes surrounded by a better heat conducting medium; this medium being the assumed allpervading universal ether, without the existence of which neither the phenomena of heat and light nor probably those of gravitation, magnetism, electricity, (and possibly those of sound) could not be explained. But since this heat conducting medium naturally must remain one and the same (the assumed ether), the change or improvement which takes place can only occur in its constitution, and I consider it possible, that during one-half of the 11 years' period its density may increase, during the other half it may decrease; during the dense ethereal periods the radiation from the sun becoming more intense, the superficial parts of the sun cool more rapidly and the maxima occur; during the rarified ethereal periods the radiation decreases, the sun's proper heat melts the products of the preceding accelerated cooling process more quickly than they can be replaced, and a minimum of spots occurs.

That during a maximum of solar spots a maximum of heat is radiated from the sun perhaps may be considered as proved by the discovery of Lockyer, that during a maximum period of solar spots the quantity of rain upon our planet is considerably more than during a minimum of spots; (compare "Kosmologische Briefe von Hermann J. Klein, Graz 1877," page 252); because more rain cannot fall, unless more water is previously evaporated from the sea; but more water cannot be evaporated, unless more heat is supplied by the sun, and more

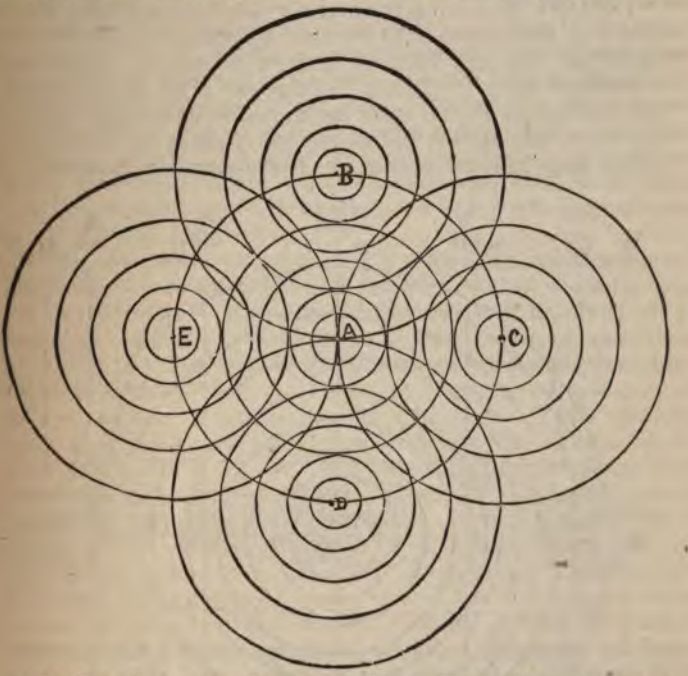
heat cannot be conducted from the sun to the earth, without the capacity of the conductor, the ether being improved; therefore the density of the ether must be subject to periodical changes corresponding to those of the solar spots, and how that is likely to effect terrestrial magnetism we shall see presently, but consider first, how this change of density possibly may happen.

If our imagination and theories fill endless space, where everything is subject to eternal motion, with assumed universal ether, we have no right to suppose that it should not participate in the motion of the stellar systems; and since all its known actions, as transmission of heat and light, are undulatory, then periodically ethereal waves of greater and lesser density may be sweeping through our planetary system, from worlds beyond and towards worlds beyond, perhaps analogue to swarms of meteorites, radiating in certain periods from certain points of the firmament; this ether being possibly not only the element in which all stellar systems are moving, but also the element, the force, by which they are being moved; for I think the possibility can be shown that the supposed ether may be the source of gravitation, the very thing which keeps the atoms of all matter near one another, leads or attracts them towards each other, and in solids, cements them together.

There is a high degree of probability that the ether filling the space of our solar system be moving round the sun in the same manner as the planets; because if the space were filled by the bodies of the system in former ages (dissolved as we might say in ether), as nebulous mass, concentrating afterwards into the various celestial bodies *rotating round the sun in the same direction*, what inducement could the ether have to do anything else?* But ours is not the only solar system in space; ours is surrounded by innumerable neighbouring ones, each possessing no doubt its own revolving ethereal atmosphere. Now, the ethereal undulations from one system must be traversing the undulations of the other systems; because if not, we would simply not be aware at all of the existence of other worlds; and that, when two or more crests of ethereal waves are co-existing (overlapping, superposing one another) in our solar system, the maximum influence of ether is manifested by increased radiation from the sun and consequently more considerable formation of solar spots and greater intensity of all terrestrial phenomena connected with the same pe-

* "Olbers maintained, that this fluid could not be at rest, but must "rotate directly round the sun." (Humboldt's Cosmos, vol. III, p. 48).

riod. But when the troughs of two or more ethereal waves occur together, then the intensity of all phenomena concerned will be less, analogue to the interference of light and other waves; this interference of ethereal waves would be acting on our system like bellows on a furnace, and from other stars possibly our sun might appear as a star of periodically variable light; or perhaps we may view our dense ethereal periods as the sum or accumulation of ethereal waves from the myriads of stars and nebulae in the milky way; or as waves overtaking or meeting the sun on his presumed passage through space. It may be remarked here that the mean periods of about 11 years are by no means very regular; (compare the tables in Dr. Klein's "Kosmologische Briefe," 2nd edition, page 220.)

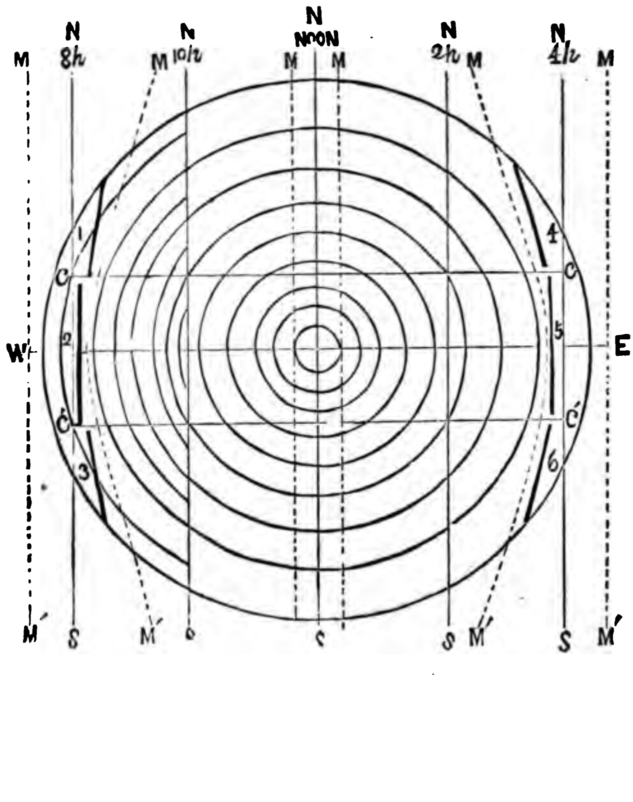


A is the solar system in space; B, C, D and E are to represent neighbouring stellar systems, and the circles ethereal undulation crests; where they coincide, maxima of density take place; where the intermediate spaces—the troughs—coincide, minima of density will happen.

How ethereal waves, therefore also maxima and minima of density, may affect the phenomena in question is well suggested by Alex. von Humboldt, in the English edition of his Cosmos, translated by E. C. Otté, London, 1868, Vol. III, pages 39 and 40 :—

"The numerous investigations that have been made in re-"cent times regarding the intimate relation between light, heat, "electricity, and magnetism, render it far from improbable "that as the transverse vibrations of the ether which fills the "regions of space give rise to the phenomena of light, the "thermal and electro magnetic phenomena may likewise have "their origin in analogous kinds of motion (currents). It is "reserved for future ages to make great discoveries in refer-"ence to these subjects." . . . .

"If electricity moving in currents develops magnetic forces, "and if in accordance with an early hypothesis of Sir William "Herschel, the sun itself is in the condition of "a perpetual "northern light." (I should rather say of an electro-magne-"tic storm), we should seem warranted in concluding that so-"lar light, transmitted in the regions of space by vibrations of "ether, may be accompanied by electro-magnetic currents."



In preceding figure W E is the terrestrial equator, C C is the tropic of Cancer, C′ C′ the tropic of Capricorn, N S are meridians from 2 to 2 hours; for the sake of simplicity and facility of demonstration we consider these meridians also as magnetic ones; the dotted lines M M′ are to represent the magnetic curves of force between the two hemispheres, according to the theory deduced in the preceding chapter; the circles are intended to denote waves of luminiferous ether striking the equator at noon during the equinoxes immediately below the sun; the effect would be the following: under the sun the supposed lines of magnetic force being struck under a right angle can deviate neither to the eastward nor westward and no diurnal variation will shew; but to the right they would be slightly deflected by the circular (or rather spherical) solar waves and the magnet at 4 (having the tendency to remain parallel to the lines of magnetic force), would show westerly diurnal variation; at 6, easterly, and at 5, none; to the left the magnetic curves of force would be deflected the opposite way and more powerfully so, because the ethereal undulations moving with the sun from E. to W. would act on the lines of force like a vessel's bows ploughing through the seas, throwing up other waves in advance; and a magnet at 1 would shew easterly, another one at 3 westerly, and one at 2 no diurnal variation.

During the summer solstice the same phenomenon would take place at C C, during the winter solstice at C′ C′, thus accounting for annual variation and why there should be a zone near the equator, which alternately, according to the declination of the sun, exhibits the phenomena of the northern or the southern hemisphere.

In the above figure to the left is the earth at the summer solstice, and the undulatory lines connecting the earth with the sun are to indicate ethereal waves, encircling the earth by inflection round it, converging near the hour angle of 12 h., like a divided stream under the stern of a vessel at anchor, producing the second tidal wave of diurnal magnetic variation.

In former ages when the earth was a nebulous mass, comparable almost to ethereal matter itself, these undulations (or radiations?) may have carried nebulous substance along with them towards a point X, and during the winter solstice towards a point Y, forming a conical tail (like a vortex) in the direction of the radius vector, as is still the case with most comets. Now if these ethereal undulations can be allowed as producing diurnal and annual variation, it is easy to see how greater or lesser density of the ethereal medium will influence magnetic variation in the same periods with the greater or lesser frequency of solar spots.

It will be noticed that this is the 3rd suggestion advanced to account for diurnal variation; the first was displacement of the earth's internal magnetic nucleus; the second was tidal motion of the earth's fluid interior; I would be most in favour of this last explanation, provided the regular turning hours of daily variation are not subject to secular change.

The various calculations introduced in several places of this essay are only to answer the same purpose as the diagrams, which are grossly exaggerated to make them more graphic; they are intended to illustrate the principle and nothing more; the data for correct calculations not yet being given, which is much to be regretted.

Humboldt says in the Cosmos that the African node (point of intersection between geographical and magnetic meridians), has been advancing to the westward, rather less than half a degree annually, and he thinks that the magnetic North Pole might be moving from west to east, the South Pole from east to west; in the Admiralty Manual it is stated that the system of magnetic lines in the northern hemisphere appears to be moving to the westward, in the southern hemisphere towards the eastward. My opinion still is, after reconsidering carefully the limited material which gradually has come under my notice while writing these several chapters, that both magnetic poles are moving from east to west, about half a degree per annum, more or less; possibly the southern one somewhat slower than the northern one, for reasons stated in a previous chapter of this appendix.

The magnetic North Pole of the variation charts for 1860 is still placed in the same position, where Captain Ross found it 1830, though I believe in 1860, it must have been from 12° to 15° more to the westward, and perhaps it would be more practical and useful to verify its position from time to time, than to be struggling in vain after the geographical pole.

If I dare to bring this Essay before the public in spite of its imperfections and many shortcomings, it is because I cherish the hope, that some more competent authority, commanding more information, leisure, and means, than myself, might undertake and succeed to sift the erroneous from the truth, to make the latter more readily acceptable.

Note.—Dr. Herman J. Klein states in his "Kosmologische "Briefe ueber die vergangenheit, gegenwart und zukunft des "weltbaues," Graz, 1877, p. 252-253, that Zoellner tried to show the casual connection between the variations of terrestrial magnetism and the state of the sun's surface, while Hornstein at the same time demonstrated, that declination, inclination and horizontal intensity are subject to periodical changes of 26.33 days' duration, and that they can only be considered as caused by the rotation of the sun; from this period the sun's true rotation would be found to amount to about 24.55 days, as deduced by Spörer from direct observations of the sun's equatorial zone.

If this influence of the sun's rotation can be accepted as existing, than it would prove that the magnetic axis of the sun does not coincide with his axis of rotation, (analogue to our planet), and during one half solar revolution one solar magnetic pole would present itself to the terrestrial magnetic apparatus, repelling the latter's pole of the same name and attracting the opposite one; during the other half solar revolution attraction and repulsion of the terrestrial poles would of course be reversed, the whole phenomenon becoming rather complicated by the earth's daily revolution, its changing distance from the sun and the latter's changing declination. Admitting that the earth be influenced by magnetism from the sun, than we must also admit, that the earth by its revolution across the field of solar magnetism may generate electric currents (atmospheric electricity, etc.) analogue to revolving metal and other bodies across the field of terrestrial magnetism (compare Deschanel's Natural Philosophy, by Professor J. D. Everett, London 1873, pages 759-760); but then the interesting question presents itself: why should the sun's magnetic axis not coincide with the axis of rotation? perhaps the answer might be that the sun's magnetic axis has the tendency to set at a right angle to the plane through the centre of gravity of the whole solar system, the latter differing, according to Laplace nearly 1° 34′ 15″ from the plane of the ecliptic, and the plane of the ecliptic forming an angle of about 7° with the plane of the sun's equator. Another interesting question would be: "are the magnetic poles of

"the sun of the same nature, as the corresponding ones of the "earth and other planets, or are they opposite?"

Note.—Since the manuscript has been returned to me, to see the proofs of the woodcuts, I have had the good fortune of reading Sir W. R. Grove's Correlation of Physical Forces (London 1874), in which on page 122 the following passage occurs, which I consider highly corroborative of my views of universal ether: "Ether, which term we may apply to the highly attenu- "ated matter existing in the interplanetory spaces, being an "expansion of some or all of these atmospheres"—(of the sun and planets, etc.)—"or of the more volatile portion of them, "would thus furnish matter for the transmission of the modes "of motion which we call, heat, light," etc.

The same eminent philosopher says in the just mentioned work, page 197: "If magnetism be, as it is proved to be, con- "nected with the other forces or affections of matter, if elec- "trical currents always produce, as they are proved to do, lines "of magnetic force at right angles to their lines of action, mag- "netism must be cosmical, for where there is heat and light "there is electricity and consequently magnetism. Magnetism "then must be cosmical and not merely terrestrial. Could we "trace magnetism in other planets and sun's, etc., it would be "a great step. . . . Mr. Airy suggests that currents of "magnetic force having reference to the solar hour are de- "tected, and seem to produce vortices or circular disturbances "and he invites further co-operative observation on the sub- "ject, one of the highest interest, but at present remaining in "great obscurity."

"Messrs. De la Rue, Stewart and Loewy were publishing a "paper, in which a new theory of sunspots is discussed.—In "this paper all differences of luminosity on the surface of the "sun are referred to the same cause, namely, the presence to "a greater or less extent of a comparatively cold absorbing "atmosphere. (Guillemin's "The Heavens," p. 44.)

The Sun's Atmosphere.—"It is not at all unlikely, that it "may even turn out to have no upper limit, but to extent from "the sun indefinitely into space."—(Ibid, p. 49.)

RETROSPECT AND CONCLUSION.

It may not be out of place at the close of these chapters briefly to review the main features of the theory as follows:—

Revolution of the magnetic poles round the geographical one in about (roughly speaking) ¾ of a millennium, probably in an epicycloidal track from east to west.

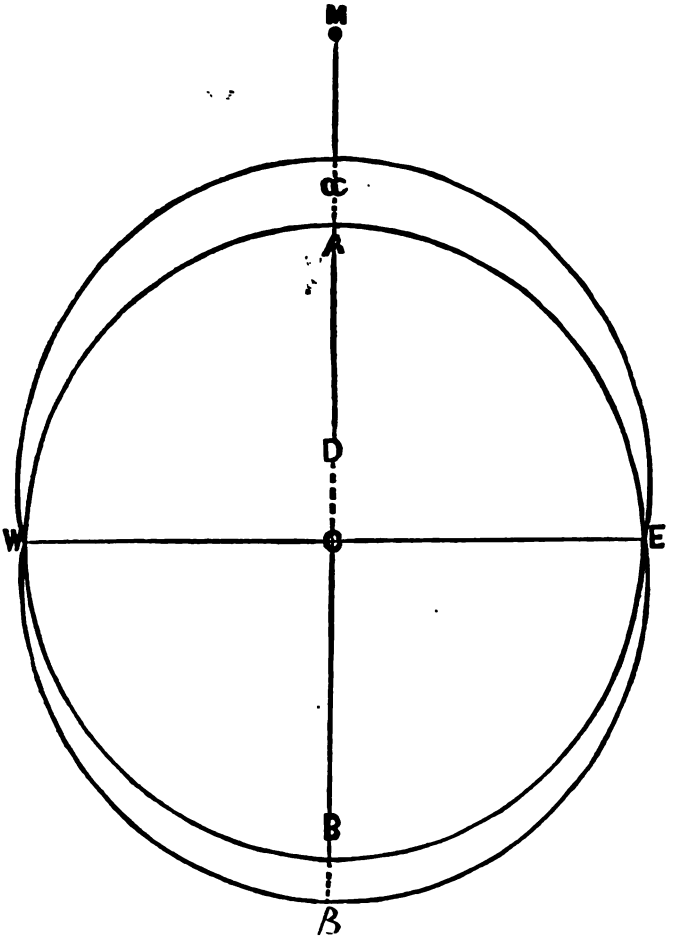
The revolution of poles is brought about similarly, as the westward tendency of the exterior ocean by the mutual attraction between the celestial bodies and the earth's interior fiery fluid conjointly with the quotidian revolution ;—the liquid portion of our planet revolving slightly slower than the solid, amounting perhaps to about ½ degree per annum.

The internal fiery fluid contains a nucleus of great density (owing to the stupendous effect of superincumbent pressure by gravity),* therefore of great magnetic capacity and coercive force, as must be inferred from Faraday's and Harris's experiments; Dr. Joule says "that steel would be compressed to ¼ of its volume at the centre of the earth." To this extremely dense, perhaps even solidified nucleus, we must look as the seat of terrestrial magnetism, round whose poles all magnetic matter collects like a liquid armature; its axis does not coincide with the axis of rotation, because again owing to the mutual attraction of the heavenly bodies and that part of the terrestrial spheroids internal molten mass, contained in the protuberance at the equator, causing a circuit of current in the fluid interior, which tends to elevate the axis of the nucleus at a right angle with the ecliptic; this tendency conjointly with the daily revolution results in an eccentric circulation of current containing the magnetic nucleus; the strength of current being influenced by aphelion and perihelion, apogee and perigee, opposition, conjunction, quadrature and declination of the celestial bodies; an unequal power of attraction being brought to bear at different times on different portions of the current, is likely to cause irregularities in its shape and motion, to which of course the liquid armature must accommodate itself, causing thereby an unsymetric distribution of the magnetic foci of unequal force; and possibly even a retardation of motion of the magnetic south pole, which irregularities are reflected by corresponding ones on the surface of the planet in the system of magnetic lines, although the latter no doubt are partly also due to the configuration of land and sea, and to the projection upon an ellipsoidal surface from an eccentric internal position.

Annual and diurnal variation are supposed to be caused by

* "It has been computed at what depth liquid, or even gaseous "substances would from the pressure of their own superimposed strata, "attain a density exceeding that of Platinum or even Iridium." (Humboldt's Cosmos, vol. I., p. 163.)

the magnetic nucleus describing a circle round its mean daily position during a revolution of the planet in the opposite direction (which former movement the magnetic poles of course must follow) in the following manner:—



Let A E B W be the earth and M the power of attraction of the celestial bodies at new moon, which will attract A most, C less, and B least; the formation of the flood wave, W α E is

the consequence, which de facto makes the terrestrial hemisphere W A E lighter, than the opposite one W B E; to restore the centre of gravity of the whole globe W A E B, some contents of the planetary shell must move and the centre of the nucleus is transferred from C to D; now if B has been attracted towards C by a centipetal force proportional to $(B\ C)^2$, then after the transfer of the nucleus from C to D, the point B must be attracted inversely less, as the square of the distance $(B\ D)^2$ has increased; the consequence of this will be the movement of B to β, and the formation of the second flood wave W β E; or supposing the excess of attraction exercised by M upon the hemisphere W A E equal to a power capable of lifting one million of tons, than $\frac{1}{4}$ million tons of matter must shift from the hemisphere W B E into the former, (or the nucleus from C to D), to restore the disturbed equilibrium of the whole. The earth revolving from west to east and D, having the tendency to remain in the direction of strongest attraction M, must describe a circle in the opposite direction; at other times than new moon, the nucleus would be moved by the parallelogram of forces of solar and lunar attraction.

From this it would appear that the centre of gravity of our planet were not geocentric, an occurrence which will seem less strange (besides the reasons already mentioned), if we consider the fact that even the position of the central body of the whole planetary system is not always in the mathematical centre of the latter, "but it actually rotates round the common centre of "gravity of the system, which occasionally falls within itself, "that is to say, remains within the material circumference of "the sun," (Ottes, Eng. transl. Cosmos, Vol. I, page 134) and "in September 1827, Schwabe discovered the eccentric posi- "tion of Saturn, afterwards confirmed by Harding, Struve, "Herschel and South," (ibid, Vol. IV, 521). Anyone acquainted with electric phenomena will conceive, that by such motion and commotion within the earth, electric currents should be generated, which joined to the probable magnetic capacity of the nucleus, will easily account for the existence of terrestrial magnetism; electric knowledge "has also thrown much light on the "internal action of terrestrial forces, since magnetism has been "recognised as one of the simplest forms under which electri- "city is manifested" (ibid, Vol. II, 727).

The description of magnetic currents given in the 5. Chap. of the Appendix as a peculiar solenoid-like closed circuit, well explaining all magnetic phenomena, I think not undeserving of

consideration, and it would be interesting to learn, if my view f tidal motion could be confirmed (4. Chap. Appendix.)

In the Journal of the North-China Branch of the Royal Asiatic Society, new series, No. X, Shanghai 1876 (Appendix II) some highly interesting remarks are contained by the Rev. Father M. Dechevreus, S. J.: "J'ai tout dernièrement recon- "nue que ces briques" (some building material used at the Zi-ka-wei observatory, nearly four miles from Shanghai), "pro- "venant du Tché-kiang, sont notablement magnétiques (celles "qui vieunent de Tien-tsin ou du Tché-ly le sont au même de- "gré) et que la correction à apporter à ces dernières observa- "tions est assez forte." . . . . . "Pendant la nuit le mouvement de l'aiguille, chaque fois que "j'ai fait des observations de 24 heures, a été excessivement "faible et difficile à saisir avec le déclinomètre;" (this would appear favourable to the view attributing diurnal variation to thermo-electricity by the sun, but Humboldt and Sabine assert, that it makes no difference in the daily turning hours, whether the sun rises very early in summer, or very late in winter; therefore I beblieve my suggestion of ethereal waves in the last chapter of the appendix a more likely explanation), In another place the able Zi-ka-wei observer states: "la declinaison mag- "nétique à Zi-ka-wei en 1874-75 aurait en moyenne, dans l'in- "tervalle de 24 heures presente 3 minima orientaux et 3 max- "ima occidentaux." . . . . . "Telle est la marche générale du phénomene; en hiver le ma- "ximum du matin se présenté après 6 h.; de même le mini- "mum du soir se rencontre avant 5 h.; de telle sorte que dans "l'intervalle de 12 heures, on peut observer dans la courbe "semi-diurne deux minima et deux maxima; bien plus j'ai été "assez étonné plusieurs fois," (on full and change of the moon?), "entr'autres jours le 6 Fevrier 1875" (new moon about 4 p.m.), "de constater l'existence, dans le même intervalle de "temps, de trois mouvements complets de va-et-vient très-bien "marqués et presque d'égale amplitude;" are these daily fluctuations indicative of the 3 distinct influences by circular motion of the nucleus, by the daily ethereal flood wave (Chap. 5., Appendix), and by the internal tides of the molten mass (Chap. 4., Appendix), the latter dependent on a "subterranean es- "tablishment of the port"?

Humboldt, to whom the science of terrestrial magnetism owes so much, repeatedly suggests various plans for investigating thoroughly these interesting and important phenomena, a correct knowledge of which is of consequence in surveying, en-

gineering, mining, travelling, strategy, etc.; but to no one more than the navigator, the shipowner and insurance companies especially since the large introduction of iron and steel into' ship building.

The fragmentary character of these pages is due to their being written at different periods of the present S. W. monsoon (1878), as the necessary information, however, scanty, gradually became procurable, and without the valuable assistance of the gentleman already named, and the kindness of the president, secretary and council of the N.-C. B. of the R. A. S. I would not have been enabled now to submit to the test of public discussion and criticism this essay on *Periodical Change of Terrestrial Magnetism.*

SECOND APPENDIX TO PERIODICAL CHANGE OF TERRESTRIAL MAGNETISM.

Various Supplementary Remarks.

Regretting not to have been able to introduce the following remarks in appropriate places of the various preceding chapters, I must apologize for intruding them now; but I could only lately write them, after the works quoted had come into my possession from the estate of a distinguished and much lamented late member of the N.-C. B. of the R. A. S.

In the journal of the latter Society, No. 2, May 1859, page 222, Captain (Vice-Admiral Sir Charles) Shadwell, C.B., H. M. S. *Highflier*, states from personal and Sir Everard Home's observations that in Singapore, Hongkong, Shanghai and adjacent places the dip (inclination) of the magnetic needle is increasing and says page 224 " all these changes can be accounted for on the supposition of a gradual increase in the amount of the vertical component of the magnetic intensity of those places."

I beg leave to point out how the increasing magnetic dip in question is explainable by the theory which I have had the honour of bringing before the same Society. Captain Ross found the magnetic North Pole, A. D. 1830 at about 97° west of Greenwich=141½° east of Shanghai; allowing about ¼° westerly motion per annum would have placed the same pole for the year 1753 in 58½° west of Greenwich, i.e. on the meridian of

Shanghai *below* the geographical North Pole, when the dip at Shanghai probably may have been near 40 degrees, because that is the amount roughly, according to the inclination chart of the Admiralty Manual at 180° from the magnetic North Pole in Shanghai latitude, 31° north; and about the year 2113 when the magnetic pole should pass the meridian of Shanghai *above* the geographical pole, the dip will probably be about 60°, because that is at present approximately its amount due south of the magnetic pole for Shanghai latitude.

These suppositions accepted, it would be clear that since say 1753 until about 2113 the dip at Shanghai must be increasing, because the magnetic pole in its secular revolution is approaching the latter place, and the nearer the pole, the greater the inclination of the needle. The same reasoning holds good concerning Singapore, although it has southern inclination; the magnetic pole to the southward of Australia in its westerly motion is approaching the meridian of Singapore, therefore the dip must increase. Sir Charles Shadwell also calls attention to the anomaly, that at Woosung, 10 miles to the northward of Shanghai, the dip on the 26th November 1858 was 45° 2′ north, 16-17 minutes less than at the latter place on the 10th of June (45° 18′ N.) and on the 16th December (45° 19′ N.) Consulting the same Society's Journal, new series, No. X, 2nd Appendix, Shanghai 1877, it will be found that on the 3rd October 1875 the dip at the Zi-ka-wei observatory was 46° 26′ 15″ north, and next month 21st November 46° 9′ 38″ north; the actual greatest difference may probably have escaped observation, because unfortunately for 1875, from April to December, only 34 observations are recorded; the amplitude of horizontal variation, more extensively observed, has certainly been greater; for the Rev. Père M. Dechevreus, S.J., states in the same place the greatest difference to have been 21.51 minutes. From this great difference at one and the same place in less than two months' interval it appears doubtful, whether the anomaly pointed out by Sir Charles really does exist, or whether it has been only accidental; the same remark applies to the observations at Kintang and Ningpo of the same paper.

There is always a fleet of native and foreign men of war in the port of Shanghai; there is a harbour master's station and a telegraph office now at Woosung; might it not be possible to make arrangements for taking a series of dip observations near Woosung, simultaneously with the Rev. Jesuit Fathers at the Zi-ka-wei Observatory, to discover the true state of the magnetic elements in the vicinity of this influential emporium of cos-

mopolitan enterprise? It is of interest and importance to study the variation of the magnetic elements in these parts of the world, in order to understand the nature of that peculiar oval of western variation, in which Shanghai is situated, and which, judging from Bohn's edition of Humboldt's Cosmos, Vol. I, pages 174-175, at Columbus's time must have been in the North Atlantic between the Azores and the shores of the new continent: "We can with much certainty fix upon three places "in the Atlantic line of no declination for the 13th September "1492, 21st of May 1496 and the 16th of August 1498. The "Atlantic line of no variation at that time ran from N. E. to "S. W."—(corresponding to that portion of the *oval* now between the Philippine Islands and the Pacific Ocean to the eastward of Japan,)—it then touched the South American continent "a little east of Cape Codera," etc.,—which latter line may have been the one now passing through Australia. Too much reliance, however, cannot be placed on those early observations, either european or oriental, for on page 175 of the same volume we read that in Paris 1669 the variation was null, while other authorities give the year 1663; on page 174 we find on the 13th September 1492 the "line of no variation was "3° west of the meridian of the island of Flores"—and in the Vth Volume of the same work, page 54, we see that the same line on the same date was $2\frac{1}{2}$° east of Corvo, Azores Islands. It is therefore all the more an important duty for the present generation to investigate the magnetic changes more minutely. From Columbus' time to its present position this interesting oasis of western declination would have performed about half a revolution round our planet from east to west in somewhat more than three centuries. Humboldt suggests repeatedly various plans for discovering the true state and nature of terrestrial magnetism; the best proceeding perhaps would be, to establish an international commission by special delegates from all civilized nations, to ascertain four or five times every century by numerous land and sea expeditions after well concerted plans the exact state of the magnetic elements all over the globe, in connection with the fixed magnetic observatories already existing; the expenses to be borne proportionally by all governments concerned. In Vol. II, No. 1 of this Society's Journal, Shanghai 1860, page 95, a supplementary memorandum by Admiral Shadwell is contained with some additional useful information concerning the magnetic elements in these regions, and I am confident, that by some more reliable observations taken in the present century the westward move-

ment of the ellipse of western declination in eastern Asia can be proved.

In No. XI of the same Society's Journal, Shanghai 1877, in a paper by Dr. J. Edkins "On the Variation of the Compass as "observed in China in the VIIIth, IXth, XIth, XIIth and XVIIth "Centuries," much valuable information is contained. Dr. Edkins says, page 140, that Mr. Wylie cited a passage from Su-kwang-ki, which states: "there is a variation for every "place. In Peking the variation is 5° 40′ east; this is found "in his work Li-yi;" page 139: "hence we learn that the va- "riation was eastern in China in A. D. 718 and at about A. D. "900. After that it became western and was so about A. D. "1080 and nearly a century later, at the time of Lai-wen- "tsiün." Dr. Edkins thinks, that since the Tang dynasty the needle may have had western declination and exchanged it again for eastern, two or three times. "Shen-kwa is quoted "as saying that in the place where he was writing the needle "persistently pointed to *ping-wei*. Transferred to our compass "this is the same as 15° to the west of north." From a remark on page 142 it seems that in 1080 and 1160 the variation in China was westerly, 7½° in the latter year.

Dr. Edkins arrives by means of Ganot's Physics, translated by Atkinson, at the same conclusion, to which I have been led by Müller-Pouillet's work. It may not be uninteresting to reproduce here, from the transactions of the China Branch of the Royal Asiatic Society, part 1st, Hongkong, 1848-50, p. 163, the following curious precept for magnetisation from the Chinese cyclopædia Tung-teen-shaou, as extracted by Dr. W. A. Harland:—

"*To make Needles point to the South.*—Take of vermillion, "orpiment and iron filings of each several fun (one fun equal "to 6.4 grains avoirdupois), reduce them to an impalpable pow- "der, and mix together with blood from the comb of a white "cock. Twenty or thirty needles are to be mixed up with this "composition, well folded in paper and placed in a furnace "where they are to be exposed to the highest heat of a char- "coal fire for seven days and seven nights. They are then to "be taken out and folded up in a piece of flesh for three days, "after which they may be removed and placed on the surface "of water to ascertain whether they turn towards the south "and are fit for use." Iron possessing the greatest magnetic capacity, when red hot, it is not impossible that the needles may acquire magnetism by induction from the earth, especially *if placed* parallel to the magnetic dip, which induced magne-

tism may become permanent, if the needles by the described procedure, (brisk insertion, whilst hot, into flesh), have become hardened, converted into steel. The Chinese do not seem to have discovered the magnetic inclination. It appears, that the manifestation of magnetism is more dependent on the extent of surface, than on the mass of magnetic bodies; an empty iron tank, for instance, according to Commander W. Walker, R.N., exercises the same influence on a compass, as a solid mass of iron of the same size; therefore it may perhaps be possible to give a greater directive force to the mariners' compass card by using hollow magnets in its construction, thereby increasing the magnetic surface of the apparatus, without increasing its weight.

The importance of the superficial area of magnets is further illustrated by the fact that several magnets closely joined together to form a magnetic battery, possess less magnetic intensity, than the sum of intensities of the individual magnets would amount to; simply because the battery exposes and affords less surface to the display of magnetic currents, than the surfaces of the single magnets amount to, when separated. Perhaps some desirable information concerning local magnetic changes can be derived from Japanese or Dutch authors, on account of the latter's early connection with Japan and Formosa; instructive records of these phenomena in China and Japan may also be contained in the Portuguese and Spanish archives in Macao and Manila. The following series of magnetic observations in the vicinity of the head quarters of this Branch of the R. A. S., Shanghai, are by high authorities, and extracted from the Society's Journal:

June 1843, dip by Sir E. Home, 44° 75′ N.

June 1858, dip by Sir C. Shadwell, 45° 18′ N.; declination, 2° 29′ W.—Race Course.

June 1858, dip by Sir C. Shadwell, 45° 19′ N.; declination, 2° 32′—Consular Flagstaff.

A. D. 1875, dip by Father M. Dechevrens, 46° 15.8′ N.; declination, 1° 59.82—Zi-ka-wei.

A. D. 1874-1875; intensity, horizontal, 6.94867; vertical, 7.25868. Total, 10.04850.

In Deschanel's Natural Philosophy by Professor Everett, London 1873, page 633, the following passage occurs: "As to "dip, its amount at Paris has continued to diminish ever "since it was first observed in 1671. From 75° it has fallen to "66°, its present value. As its variations since 1863 have been "scarcely sensible, it would seem to have now attained a mi-

"nimum to be followed by a gradual increase." By an inspection of the figures on page 631 of the same work, it will be remarked that the isoclinal lines form more or less regular ellipses round the magnetic poles, which in several parts of their configurations almost coincide with the parallels of latitude for some distance; such a coincidence of secular motion has probably happened in 1863 at Paris, when the dip will appear stationary for some time. A similar thing may happen in regard to the *western declination in China*; the greater axis of the oval running north and south, the northern and southern parts of the oval isogonic lines will nearly coincide with the parallels of latitude, and when the maximum of western variation is reached at any place it will remain stationary for some time, and then it will decrease. This hypothesis applied to the above table from the Society's Journal, it would appear, that since Sir Charles Shadwell's observations of the declination the north and south axis of the oval must have been passing towards the westward.

According to the international code of signals, London 1877, page 233, the magnetic declination has decreased about a quarter of a point during the last fifteen years in England. By a careful perusal of the Admiralty Manual of Scientific Enquiry, London 1871, my opinion concerning tidal motion appears confirmed by the following sentences: "With regards "to the stream of flow and ebb, they are often not merely two "streams in opposite directions at different times of the tide; "they generally turn successively into several directions, so as "to go quite round the compass in one complete tide, either in "the direction N. E. S. W. with the sun"—(in places to the northward of the sun?)—"or N. W. S. E. against the sun," pages 71-72—(in positions to the southward of the sun?)—"In "all land areas in the northern hemisphere the wave of high "water tends to revolve round the coast in the direction of the "hands of a watch and in like areas in the southern hemis-"phere against the hands of a watch; leaving out of the ques-"tion the theoretical (Mr. Carrick's) considerations, on which "are based these results, the degree of truth contained in the law, "regarded merely as empirical, *is worthy of very severe scrutiny.*"

Much less appears actually to be known yet of tidal movements than is generally supposed; "the general progress of the "tide wave along even the most frequented shores is still im-"perfectly known; and about the connection of the tides over "the general areas of large oceans we are as yet entirely in the "dark; there is therefore an ample field of important and use-

"ful discovery in this subject," (page 78) and "in the central "parts of the Pacific the tides are small and anomalous, for "they do not clearly depend on the moon," etc., etc. It is possible, that the last mentioned phenomenon may be due to the very probable fact, that the earth's solid crust covered by the Pacific may be thinner, than at other portions of our planet and therefore the outer crust, ocean and interior fiery fluid matter *together yielding more equally* "to the deforming influences of "centrifugal force and the attraction of sun and moon," (Mr. Kingmill's Borderland of Geology and History, page 5), which would certainly have the influence of letting the oceanic tides appear "small and anomalous."

The same remark applies to Batavia; "by accurate observ-"ations made in 1839 at Onrust, it seems that the tides and "rise and fall are not subject to fixed rules. The mean rise "and fall was two feet, and the maximum and minimum four "feet." (Findlay's Sailing Directory for the Indian Archipelago, China and Japan, London, 1870, page 613.)

I must acknowledge with thanks that I have been under obligation, when writing this second appendix, to the kind assistance of Mr. John Christie, chief engineer of the China Navigation Company's steamer *Chefoo*.

After the above lines had been sent to press, I have been favoured by the urbanity of the talented and zealous director of the magnetic and meteorological observatory at Zi-ka-wei, the Rev. Father Marc Deehevrens, S.J., with his reports for 1876-77 and a general resumé for 1878, from which the following facts are extracted:—

	1876	1877	1878
Declination	2° 1′ 24″ W.	2° 1′ 21″ W.	2° 0′ 04″ W.
Inclination	46° 13′ 43″ N.	46° 13′ 38″ N.	40° 13.4′ N.
Horizontal } Compo-	6.95131	6.9637	6.9770
Vertical } nent ...	7.25602	7.2684	7.2815
Total Intensity	10.04924	10.0656	10.0846

The learned and Reverend Father states in regard of the mean values for the inclination and intensity in 1878 that during the months of May and June the observations had to be interrupted: "les travaux d'agrandissement de notre salle

" magnetique m'ont forcé à interrompre les observations direc-
" tes d'inclinaison et d'intensité."

In his "Bulletin des Observation de 1876" Father Deehevrens describes an ingenious apparatus in use at Zikawei; " cet appareil à lui seul pourra, avec un chronomètre, consti-
" teur tout le bagage scientifique et géographique à travers la
" province, servant tout à la fois de théodolithe et de boussole
" pour l'inclinaison, la declinaison et l'intensité magnètiques." If all Meteorological Observatories were supplied with this useful instrument, the mysterious periodical changes of terrestrial magnetism in the Far East would be much sooner revealed indubitably, than can be done by the solitary efforts of a single institution, although the observations be carried on in such a careful, intelligent and skilful manner, as at the excellent Zikawei Observatory; only by many valuable observations in numerous localities and extended over *long periods of time*, this interesting and important problem can be solved; a truth, beautifully illustrated by the Hexameter, which King Ludwig of Bavaria, caused to be engraved near a picturesque waterfall in the Alps:

" Gutta cavat lapidem, non vi, *sed saepe cadendo.*"

I believe I cannot close these pages in a more appropriate manner, than by the remark from the illustrious Humboldt's Cosmos (Bohn's edition, Vol. II, page 720), that " several times
" every century an expedition of ships " (in conjunction with the fixed observatories ashore and land expeditions) " should be
" sent out to examine as nearly as possible *at the same time* the
" state of the magnetism of the earth, so far as it can be in-
" vestigated in those parts covered by its ocean. May perma-
" nent scientific institutions (Academies) impose upon them-
" selves the practice of reminding every twenty-five or thirty
" years' governments, favourable to the *advance of navigation*,
" of the importance of an undertaking, whose great cosmical
" consequence depends on its long continued repetition."

THE END.

ERRATA.

Page 2—Middle of page read 1663 instead of 1163.
,, 4—Middle of page read (Celsius) instead of (celsius.)
,, 10—Middle of page read "do not coincide" instead of "does not coincide".
,, 10—12th line from bottom read "diurnal" instead of "diurned".
,, 11—11th line from top read "observatories" instead of "observations".
,, 12—10th line from top read "1841, angle" instead of "1841. Angle".
,, 14—10th line from top read "armature" instead of "armisture".
,, 16— 7th line from top read "elliptic" instead of "ecliptic".
,, 16—17th line from bottom read "full or new moon" instead of "full moon".
,, 21—13th line from bottom read "Sabine" instead of "Sabini".
,, 32—12th line from bottom read "Stromboli, (volcanoe)" instead of "Stromboli (volcanse.)"
,, 33— 6th line from bottom read "relations" instead of "rotations".
,, 33— 9th line from bottom read "statical" instead of "statistical".
,, 33—17th line from bottom read "noyau" instead of "noyan".
,, 33—Middle of page read "Hansteen" instead of "Hausteen".
,, 34— 9th line from bottom read "closer" instead of "closed".
,, 34—The sentence "On the 1st of September," etc. should have been printed as a note to the 6th Chapter of the first Appendix.
,, 36—5th line from bottom add: "I copy as follows:"
,, 37—17th line from top read "exist" instead of "exists."

ADDITIONAL ERRATA.

First page of preface, 9th line from bottom read "remained" instead of "remanied."

Page 2—21st line from bottom read "minimum" for "maximum."

„ 5—22nd line from bottom read "specific" for "specified."

„ 20— 6th line from top read "hemisphere" for "hemispheres."

„ 27— 2nd line from top read "Gales" for "Galese."

„ 28—16th line from top after "directions" add: were.

„ 29— 1st line from top read "current" for "currents."

„ 29— 4th line from top read "similar" for "singular."

„ 29—12th line from bottom read "Su" for "SN."

„ 31— 7th line from top after "which" add: according to.

„ 32— 6th line from bottom read "Dr. Brünnow" for "Dr. Brünnout."

„ 33—middle of page read "Biot, Hansteen and others have had."

„ 49—15th line from bottom read "then" for "than."

„ 54— 6th line from top read "Dechevreus" for "Dechevreus."

„ 54— 7th line from top read "reconnu" for "reconnue."

„ 54—10th line from top read "viennent" instead of "vieunent."

„ 54—21st line from bottom read "presenté" for "presente."

„ 54—18th line from bottom read "presente" for "presenté."

„ 62— 6th line from top read "constituer" and "géographique" instead of "constiteur" and "gêographique."